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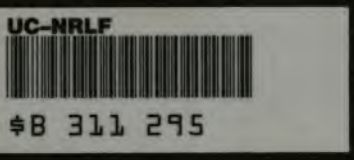

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Report of the Transvaal Commission on the Use of Winding Ropes, Safety Catches and Appliances in Mine Shafts

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REPORT OF THE TRANSVAAL COMMISSION ON THE USE OF WINDING ROPES, SAFETY CATCHES AND APPLIANCES IN MINE SHAFTS.*

*The reader will note that the numbering of the paragraphs (which we have retained as in the original report, inasmuch as cross-references are made later by means of the numbers) begin with 18. The first 17 paragraphs of the report form the preface, which we give below rather than at the head of the text. "Your Excellency," referred to in the preface, is the Right Hon. Earl of Selborne, Governor of the Transvaal, who appointed the Commission on March 8, 1905. The preface follows:

1. The Terms of Reference to Your Excellency's Commissioners were more especially to inquire into and report on the following matters:

(I.) Winding Ropes.

(II.) Safety Catches and Safety Appliances Suitable for Winding Operations.

2. In view of the comprehensive character of the Terms of Reference, it was considered essential to seek and admit full oral and written evidence from those competent to give it, not only in the Transvaal, but in all countries in the world where mining work is carried on.

3. It therefore became necessary to indicate to the public the points upon which the opinions of witnesses were to be invited. This was done by means of schedules, setting forth the subjects of the inquiry.

4. Schedule No. 2, of which no less than 4,000 copies were distributed throughout the world, contained a most detailed classification of the points concerning which the Commissioners desired the opinion of witnesses, and elicited valuable information.

5. Through the medium of His Majesty's Ambassadors in Germany, Austria, Russia, France, and Belgium, numerous communications were received from these countries, especially in respect of the mining regulations referring to the safety of persons traveling in shafts.

6. The witnesses were either invited to give, or, in response to advertisement, proffered their evidence. They represented the views of wire-rope manufacturers, engineers, mine managers, engine drivers, riggers, wire splicers, miners, etc.

7. Except in two instances, all practical tests of safety appliances were held on the property of the Langlaagte Estate and Gold Mining Co., Ltd., at the Marcus shaft, which was kindly placed at the disposal of the Commission on the agreement that the cost of equipment, and of damage done, would be reimbursed to the company.

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8. In view of the possibility of safety devices for use in inclined shafts being submitted to the Commission for trial, an examination of the Central Inclined Shaft of the Bantjes Consolidated Mines at Florida was made on Dec. 14, 1905, by Mr. W. Martin Epton (Inspector of Machinery) and Mr. C. J. Price. They reported that the center compartment of the shaft and the hoisting plant, engines, boilers, etc., appeared to be in good order and could be put into working condition at very little cost. As, however, no safety catch suitable for use in inclined shafts was recommended by the Sub-Committee for trial, it was not found necessary to make use of this shaft.

9. Under Executive Council Resolution No. 1,468 of 1904, the sum of £2,000 was granted for the practical testing of such safety appliances as the Commissioners considered worthy of trial.

10. The Commission consisted originally of 23 members, all technical men, who served in an honorary capacity.

11. During the course of the inquiry, three of the Commissioners, namely, Messrs. G. B. Poore, R. M. Catlin, and F. Drake, resigned in July, 1905, January, 1906, and July, 1906, respectively, owing to their permanent departure from the Transvaal; and Mr. K. Schweder resigned in February, 1907, as he had invented and was exploiting a safety catch and did not, therefore, consider it desirable to continue to sit on the Commission. Mr. J. A. Hebbard was appointed to take the place of Mr. Poore, but the other vacancies were not filled, in view of the fact that 15 members formed the necessary quorum.

12. Mr. Schweder continued to place his services at the disposal of the Commission, and his contribution on the subject of the safety catch designed by him is included in this report.

13. In February, 1906, the Chairman proceeded on long leave to England, and was absent for seven months, during which period Mr. J. A. Vaughan acted as Chairman.

14. Of the four sectional committees which were formed to consider more particularly the sub-divisions of the Terms of Reference, that dealing with the consideration of safety appliances was constantly at work. Eighty-four designs which complied with the Commission's requirements, as published in Schedule 2, were thoroughly considered, and many of the better designs were reconsidered several times. Many crude designs, which did not comply with instructions, were not formally brought before the Committee, but, in addition to the ideas of a great number of possible inventors who called on the Secretary, were considered and advised upon by Mr. J. A. Vaughan.

15. It was a condition imposed upon all inventors and others who submitted models that such models were to remain the property of the Transvaal Government. Many interesting and clever models have been received, and are stored at present in the offices of the Mines Department, Johannesburg.

16. The Commission desires to place on record its

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appreciation of the valuable assistance of Mr. Max Baumann of the New Rietfontein Estate Gold Mines, Ltd., for his excellent translation of the most important German communications.

17. The first sittings of the Commission and of the Committees were devoted entirely to matters of procedure and to the preparation of the schedules. The first public sitting was held on March 21, 1907. There have been many unavoidable adjournments, owing mainly to the nature of the work of the Committee on Safety Appliances, and to the practical tests at the Langlaagte Estate Mine, which have delyed the preparation of this report.

Historical.

18. The subject which this Commission has been appointed to investigate is not a new one. It has, in fact, for many years continued to attract public attention in all countries where mining is carried on, especially in the United Kingdom and Germany. There has been, however, some diversity of opinion among the various authorities as to the best means of promoting the safety of persons and property in mine shafts, British opinion being, as a rule, more conservative than Continental, and more or less averse to the employment of safety appliances as complicating the conditions of raising and lowering without positively securing any compensating advantages.

19. The appointment of the Commission was due mainly to two circumstances, namely:

(1) The distressing accident which occurred at the Robinson Deep Gold-Mining Co., Ltd., on April 25, 1904, following on a similar accident at the Geldenhuis Deep in 1901, when, in the former case, a flat winding rope composed of steel wire broke and precipitated to the bottom of the shaft a cage full of natives, numbering 44, all of whom were killed; and

(2) A number of inventors in this and other countries having, in consequence of the above-mentioned and previous failures of winding ropes or their attachments in various mining centers, turned their attention towards the improvement of existing devices for preventing the uncontrolled descent of skips or cages in the event of the winding rope breaking, as well as those for restricting the damage to life and property caused by the inadvertent hoisting of such conveyances beyond the normal terminus in the headgear.

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20. Several persons in this Colony have directed a large amount of energy to the subject, more especially to the former section of it; and, struggling with praiseworthy persistency against the various difficulties incidental to practical trials and experiments, have submitted designs and models to the Mines Department. Some of these were highly ingenious and, in a few instances, novel; but in most cases the ideas advanced were simply modifications of the better-known types of unreliable safety catches already in use. It was felt, however, that the degree of interest which had been aroused in this important subject, and the amount of endeavor which had been devoted to ensure success, should not be allowed to dwindle away without securing for the service of the mining community whatever tangible benefits might be possible.

21. Although Commissions of Inquiry had, in past years, investigated this and kindred matters in Europe, it was generally considered that—owing to the rapid evolution of engineering science as applied to mining practice, due principally to large and growing increases in the scale of operations and in the depths at which they are conducted and projected, necessitating the hauling of men and minerals at a higher speed and in greater quantities—a thoroughly representative committee of mining men in this Colony should take up the work where it had been left off by others, and, after investigation, test under practical conditions such devices as might appear to give promise. Such a committee would, it was hoped, render good service in eliminating ideas which were unsound in theory and which tended to hamper the efforts which have been so doggedly directed towards the solution of this important problem, and tend to concentrate the energies of those who have the subject so much at heart, along those lines which would appear the most likely to lead to ultimate success.

22. In all other countries where up-to-date mining is practised, such as Great Britain, the United States, Germany, Belgium, France, Australia, etc., public interest had been aroused whenever the failure of a winding rope had caused the loss of a number of lives. The first safety catch of which there is any record as having

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been used successfully, is that of Fourdrinier in the year 1851; this was of the wedge-spring type.

28. With the introduction of safety catches and the influence of the Coal Mines Regulation Act, which came into action in the early '50's, the beneficent results shown in the following tables were achieved.

The proportions of fatalities to men employed in British mines, due to hauling accidents and falling down shafts, etc., were:

Years	1850—1860,	1	killed for	1,161	employed.
"	1861—1870,	1	"	2,121	"
"	1871—1880,	1	"	3,557	"
"	1881—1883,	1	"	4,718	"

24. This consistent diminution in the proportion of men killed is due to improved methods and appliances, among which detaching hooks and safety catches form a not inconsiderable part, combined with increased care on the part of all concerned.

25. In England a Royal Commission, under the presidency of Sir Frederick Abel, was appointed in the '80's; the report of this Commission, however, was not in favor of the employment of safety catches.

26. In the course of the inquiry of the Abel Commission it was pointed out, as a reply to those who objected to safety catches on the ground that "a good rope is the best safety catch," that some disasters had occurred irrespective of the quality or condition of the rope.

Since that time there have been several instances of this nature, notably that at Tirpentwys Colliery, Monmouthshire, in 1902, whereby eight lives were lost through the breaking of a rope owing to its being knocked off the pit-head sheave. This fact caused the Government Inspectors of Mines to consider seriously the advisability of enforcing the use of safety catches; but after a full inquiry into Continental practice, the Inspectors were still unconvinced of the desirability of taking such a step.

27. Another serious rope accident, which may be described as the fracture of a rope through an overwind, and which resulted in the death of 17 miners, took place at the General Blumenthal Mine in Germany in 1898, and caused the appointment of the Dortmund

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Mining District Commission in the following year. The recommendations of this Commission were:

(1) That speed safety appliances—that is, those contrivances which prevent excessive speed overwinding and overlowering by automatically closing the throttle-valve and applying the brake—afford greater security than those contrivances with indirect action, such as warning bells, etc.; but the degree of perfection attained is not sufficient to justify their compulsory adoption, and it was recommended that every assistance should be afforded to those endeavoring to improve them.

(2) Recording speed indicators should be attached to winding engines.

(3) Converging guides, where there is sufficient head room, are of use in case of overwinding even if they fail to hold the cage, inasmuch as their retarding action may allow time for a safety catch to come into action; although there are very few cases in which the braking action will extend over a sufficient distance to absorb all the momentum, or even sufficient of it to prevent the breaking of the rope.

(4) Catchbeams in the headgear, which are in very general use in the Dortmund District, are almost unanimously approved by mining officials. In case of overwinding, the lever arms of these appliances automatically fall inwards into the compartment after the cage has passed upwards, and afford a stop or bar which securely holds it against descending.

(5) Rope-detaching appliances should be used only when it is impossible to employ simpler means, such as converging guides, etc.

(6) The weakest parts in a rope which has been in use for some time are: (1) near the capping; and (2), between the drum and the pit-head sheave when the cage is at the bottom of the shaft.

(7) The regulation safety factor of 6 is deemed sufficient.

(8) Taking the period of 1890 to 1902, the various safety catches in use in the district acted successfully on 126 occasions, acted 87 times when not required, and failed to act 54 times. Several of the last mentioned cases were due to the neglected condition of the catches, shafts, and guides.

Regarding the compulsory use of safety catches, the Dortmund Commission (without ignoring the fact that no safety catch yet produced is infallible, on the ground that the proportion of success to failure during the

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above period of 12 years is as 24 to 12, and that there is no case on record of personal injury due to the action of safety catches) is in favor of their retention until statistics prove that they cause more accidents than they prevent, subject, naturally, to their being kept in perfect order and having the springs frequently and periodically renewed. Furthermore, the guides should be of sufficient strength and section and should be regularly inspected. As the most effective way of preventing untimely action when hoisting minerals, the catches should then be put out of gear if practicable.

28. The reports referred to have been at the disposal of the members of this Commission, and have been of assistance in keeping the present investigation within reasonable bounds by the elimination of questions that had been already quite settled, and thus emphasizing the importance of the undecided factors.

29. In the report which follows, the subject matter has been treated as far as possible in accordance with the classification adopted in Schedule 2.

Winding Ropes (Structure).

30. The Commission has been especially fortunate in securing the testimony of a large number of prominent manufacturers of winding ropes; and their opinions with one exception, are all in favor of the use of "Lang's" lay ropes for winding in shafts where the conveyance is guided, i. e., kept from swinging and rotating. One manufacturer, while favoring "Lang's" lay for general use, states that ordinary lay is better for small drums, because a larger number of wires, and therefore smaller sized, may be used in the strands; in "Lang's" lay the wires would tend to untwist. Apart from the evidence of manufacturers, two American engineers were in favor of the ordinary lay for all cases. Locked-coil ropes are recommended by one manufacturer, but their suitability for the conditions obtaining in Transvaal mining operations is not considered to have been established.

That the deterioration of a winding rope should be susceptible to detection by a competent person, while making the customary examination, is a most essential point; and, although this can never be absolutely secured,

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it is considered that the rope constructed of six strands of seven wires each lends itself most readily to complete examination. It is also the most easily spliced, besides which a more even distribution of the working load over all the component wires is assured than is the case with ropes of other constructions. The center wire of the strand may not be thoroughly effective, but that it adds to the strength of the rope when made of high-grade steel has been established by many tests.

The limitation to the general use of the 6.6.1 rope lies, of course, in the fact that the wires for big breaking loads would become of too great diameter. Its use in the medium sizes (1-in. and 1⅛-in. diameters) on these mining fields has been discountenanced on account of the many small-sized winding drums, and the fact that the ratio of D to d—i. e., the diameter of the drum to the diameter of the wire—becomes less than 800 to 1; but there have been many instances of the 1⅛-in. diameter ropes of 6.6.1 construction giving most satisfactory results when winding on drums of less than 8-ft. diameter.

It may be stated with some certainty that the bending stresses to which winding ropes on the Rand are usually subjected constitute, save in exceptional cases, quite an unimportant factor in limiting their lives. While there have been cases of ropes used on sheave hoists giving out through the breakage of many numerous undivided wires, owing to excessive bending, it is more usual in drum hoists for frictional wear or crushing stresses to be the most important deteriorating influence.

31. From statistics furnished by the Mines Department, the following information has been prepared showing the various kinds of winding ropes now in use in the Transvaal for raising and lowering persons; about 50% are used for rock as well:

Kind.	Number.
"Lang's" lay	416
Locked-coil	0
Many-stranded	2
Ordinary lay	5
Flat	4
Flattened strand	0
Total	427

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Of the 416 "Lang's" lay ropes, the sub-division according to construction is approximately in accordance with the following table:

Construction.	Number.
6.1	189
8.6.1	85
7.5.1	69
9.6.1	33
9.8	17
8.5.1	13
12.6.1	7
9.5.1	2
9.4.1	1

32. It will be noticed that ropes of compound construction are largely used, and the reason for this practice may be seen in the following tabulation of the value existing for D:d at shafts where persons are raised and lowered:

Value of Ratio D : d	Percentage of Total Number of Winding Ropes.
Under 500	4.6
500 to 600	6.6
600 to 700	12.9
700 to 800	16.7
800 to 900	19.8
900 to 1,000	17.5
Over 1,000	21.9
Total	100.0

33. Whether the working conditions disclosed above in the matter of bending stresses be considered favorable or unfavorable, the fact remains that the average winding rope has a far shorter life on the Rand than on other mining fields. This fact was agreed upon by many witnesses; and the reasons assigned were corrosive water in shafts, unfavorable mechanical conditions, lower initial factor of safety, and higher final factor of safety.

Leaving for a time the full consideration of these cases, and returning to the matter of the most suitable kind of winding rope, it remains to be noticed that ropes of ordinary lay have been used successfully for sinking purposes where a "dead" rope was required, as in the case of a bucket or kibble being used. The spinning of the conveyance can then be prevented, but the swinging effects may still occur; and these effects have

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been so dangerous at greater depths that sinking by means of a skip with extension runners has been resorted to. A great deal of evidence was taken dealing with the relative safety of sinking by means of a skip or sinking with a bucket, and this will be alluded to later.

34. Dealing now with the "lay" of the rope, it appears that most manufacturers endeavor to make the rope as "dead" as possible, consistent with flexibility. Regarding the circumference of the strand as one-third of the circumference of the rope, the practice is to vary between 2 to 1 and 3 to 1; i. e., if the length of the lay of the strands in the rope is 9 ins., the length of the lay of the wire in the strands will be from 4½ ins. to 3 ins., according to the particular maker's practice. Most manufacturers keep more nearly to the 2 to 1 rule, but the manager of one large and important factory considers, after repeated experiments, that the 3 to 1 rule is the best, this bringing the angle of the lay of the strand in the rope exactly the same as that of the wire in the strand. This rope, while flexible, is very "dead;" and this practice permits of small ropes with very fine wires being constructed "Lang's" lay, which, as previously stated, is otherwise impracticable, as they would become untwisted as soon as they were cut.

Other ways of constructing a "dead" rope, besides "ordinary lay" and "locked-coil," are "flattened strand," "many-stranded," or by having the wires of the core of the strand twisted in the contrary direction to the outside wires of the strand. Of all these methods, the ordinary lay seems the least open to objection, the wires being all circular and well locked together. Compared with "Lang's" lay, and considering that the wires at the crown of the strand are set practically parallel to the axis of the rope, and also that an individual wire comes to the crown just twice as frequently as in the "Lang's" lay rope, broken wires should be of more frequent occurrence; but, on the other hand, the fractures will occur at places where their detection is the most easy matter, and their weakening effect is probably less owing to the more complete locking of the wires. So that if "Lang's" lay cannot be used on account of its untwisting, then ordinary lay appears to be the next best.

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35. With reference to the "many-stranded" ropes in use on the Rand, the experience of their working is at the present time too short to enable it to be decided whether they will outlast the usual makes of winding ropes. The construction is 12 strands around 3 strands. The outside strands are made up of 4 wires around soft wire, and the inside strands are each composed of 3 wires around a hemp center. This rope does not rotate. The inner and outer portions of the rope are each "Lang's" lay, but one is left-handed and the other right-handed.

36. Regarding the core of the strand, as far as the evidence adduced goes, if this is made of hemp the strand is unable to keep its shape under heavy pressure such as a winding rope is subjected to, unless wound on the drum in only a single layer. So long as the strand keeps its shape and the bedding of the outer wires remains close, the hemp core, well-dressed initially, may materially assist in preventing internal corrosion; but when deformation occurs, water finds its way inside the strand, the hemp gets "chewed up" and washed out, and the conditions are then exceptionally favorable for internal corrosion.

37. With regard to steel cores, the weight of opinion is against any specially shaped core—triangular or tape—it being considered that these are likely to nick or cut the wires that rest on them. That the core wire should be circular is generally agreed, but there is great difference of opinion regarding the tensile strength of steel that should be used. The most modern practice appears to be to use a class of steel similar to, or at any rate but slightly lower in tensile stress than that of the outer wires. The tests in the Mines Department Laboratory conclusively prove that a hard-core wire does add materially to the strength of the rope, and experience of the examination of many samples goes to show that these core wires are no more liable to fracture than those made of annealed steel or iron. Steel core wires, whether soft or hard, whether broken or not, help to maintain the shape of the strand, and local evidence points to the advantage of using wire of high tensile strength.

38. In spite of Professor Hrabak's condemnation of the wire center on theoretical grounds, this Commission

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considers it quite unproved practically that the hemp core is superior.

89. With respect to the question as to what proportion of strength can be assigned to a steel wire core in the strand, this can only be answered correctly after examining the records of many more tests than have been undertaken up to the present; but it may be remarked that so long as the strength of the rope is ascertained by actual test of a whole specimen of adequate length, no uncertainty can exist on this point, the combined efficiency of the wires being then exactly determined.

40. The main core of a winding rope should be of the best hemp or manila, of good long yarn, laid up to form a tight rope, well soaked in boiling tar and treated with some non-acid lubricating composition. No tensile strength can be expected from this hemp core, but it should be made up tightly enough to form a firm center that will keep the strands in place and the rope in shape under a considerable crushing pressure, such as exists when the rope is coiled in several layers (riding turns) on the drum. Cases were brought to the notice of the Commission in which the fiber core consisted of untarred jute, of short yarn and unlubricated. A rope with a core of this description, when working in a wet shaft, has but a very short life, the jute becoming washed out and the rope flattening and having its lay straightened out in places. The engineer, having then no confidence regarding the even and fair distribution of the load among the component wires of the rope, takes it off; that is, unless the damaged portion can be cut off the end of the rope and still leave a sufficient length.

41. When a rope of compound construction is used, the outer wires should be of as large gage as possible consistent with the size of the drum and sheave. Between the limits 6.1 and 12.6.1, in each of which constructions the wires are of the same size, there are many variations—such as 8.6.1 and 7.5.1—in which the outer wires are larger than the inner ones. Ropes made up of these strands have larger wearing surfaces to meet friction and corrosion.

42. It appears possible to construct parallel ropes of great length without any break in the continuity of the wires. Many manufacturers, however, appear to regard

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this as quite an unnecessary refinement, and join shorter lengths of wire together by brazing. The brazed joints in the various wires should, as far as possible, be so arranged that they are not too nearly adjacent. The braze is made on a taper about five to seven times as long as the diameter of the wire. The heat necessary for the operation softens the wire somewhat; so that, although the actual joint may be stronger than the wire in tension, breaks often occur when the rope is in use at distances of from an eighth to a quarter of an inch from the braze.

43. Manufacturers differ considerably as to the best method of constructing a tapering rope. The plan most favored is to keep the same number of wires in the strands for the whole length of the rope, and to make the taper by brazing on, at each step, wires of slightly smaller diameter, keeping the joints of the several wires widely distributed. The other plan is to drop out wires from time to time; for instance, one sample of tapered rope of compound construction had strands of 12.6.1 at the large end, 11.5.1 at the next step, 10.4.1 at the next, and 9.3.3 at the last stage, the innermost three wires being very fine ones put in merely for packing. In this method of construction the outer wires are of uniform section throughout, as are also the inner wires. This is claimed as an advantage, especially for use with conical drums where, if the wires are not of the same size, they will be too large for use on the small end of the drum or of too fine a gage for the large diameter. On the other hand, some of the advocates of brazing regard the older practice of dropping wires as dangerous.

44. The perfect method of constructing a taper rope would be to lay up tapering strands of tapering wire, but at the present time it is practically impossible to draw such wire. The tapered ropes at present supplied to the mines on the Rand number only two, and only one of these has been put into use. In view, therefore, of this limited experience, the Commission is not prepared to express any preference; but it does not condemn the practice of dropping wires, which may be regarded as quite safe if properly carried out.

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Winding Ropes (Material).

45. The various grades of steel used in the ma facture of winding ropes are designated in an arbitr and somewhat misleading fashion. Such terms as " proved patent crucible," "best patent crucible," "mil "best," or "improved plow," are used by many mak but not as denoting any exact standard of ten strength.

46. The fundamental difference between so-called "cr cible" steel and "plow" steel is that the iron bas used in their manufacture are not the same. Plow st is made from a base of the finest quality, and crucib steel from some cheaper iron, these two varieties beir represented respectively in English practice by "Swedish and "Cleveland." The Siemens-Martin process is use either acid or basic. In the basic process a low-grad iron may be used, possibly highly phosphoric, while th acid process is suitable for the higher grade only.

Other differences between "crucible" and "plow" steel are the outcome of manufacture—e. g., the heat treatment, and the number of passes through the dies. Continued drawing will increase the breaking stress of a wire. The lower the quality of the iron from which the steel is made, the quicker will this steel harden up—i. e., the fewer draws will it require. The heat treatment, or tempering process, is introduced to give toughness to the wire, and not to increase the tensile strength. Owing to the fact that the manufacture of high-grade wire is practically a secret process, it has not been possible for the Commission to get anything more than the barest information.

47. It is known with certainty, however, that wires which are called the same, and which test the same, are yet very different in price, and give very different results in use, especially when the working conditions are severe. The tests alluded to here are the old-established chemical and mechanical tests. In the chemical test, carbon, silicon, manganese, sulphur, and phosphorus are first determined, and the amount of iron is then arrived at by difference. From the results of recent researches, it appears that hydrogen and nitrogen exist in steel and deleteriously affect the quality, so that

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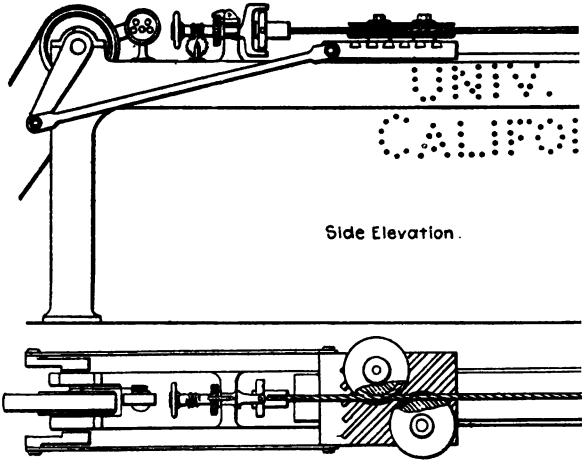

The machine is constructed to subject the specimen simult to intermittent flexure through any desired angle and restr without reversed bending, applied successively over a subst length; to friction upon pulleys, and also, if desired, upon cases also to torsion. It is suitable for testing single wires o

There is a main framework, a fixed headstock, and a tails longitudinally on the table upon a guide. The specimen is h convenient construction, secured to the stocks by universal joi bals illustrated. The purpose of these connections is to obvi specimen at the mouth of the grips.

Tension is applied to the specimen by means of the adjustab to the tailstock by a flexible connection which passes around a means for applying and indicating the tension may be modified of the specimen which the machine is designed to test.

To enable the specimen to be twisted, the head gimbal has which rotates in the headstock and is secured therein by a coll keyed a hand wheel for rotating it, and a detent and detent wh hold the shaft in the desired position. An indicator shows the the specimen has been twisted.

A table, mounted upon a suitably constructed guide, slides nal direction upon the frame. The upper surface of this tabl undercut grooves by which one or more grooved pulleys may table at any desired point. About such pulley or pulleys the as may be desired for any individual test. In the plan two pul the specimen is passed around each one in succession.

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the complete ignoring of these elements is no longer possible.

In the mechanical test, steel wire is tested as to its ability separately to stand tension, torsion, and bending. Recent investigations have shown, however, that wires in reality of poor quality, and which still come well up to the standard of these tests when conducted separately up to breaking load, have had their inferiority disclosed by means of combined tension, torsion and bending tests rapidly repeated in a manner which closely resembles working conditions at stresses below the elastic limit of the material.

48. A drawing and description are shown here of a machine designed by Messrs. Vaughan and Epton, for the purpose of testing wires in this way.

49. With regard to the ductility—i. e., the non-brittleness—of the finished wire after the drawing and heat treatment, this depends on the care and skill exercised, as also on a knowledge of the drawing steps and limits suitable for the particular class of steel used. With this qualification, it may be stated that ductility is not sacrificed in the gain of tensile strength. Seeing, however, that the large majority of rope manufacturers purchase the finished wire, they are not in the best possible position to apply the results of experience gained as to the working life of various qualities.

Mr. J. Dixon Brunton, of Musselburgh, kindly furnished the Commission with a copy of his paper, "The Heat Treatment of Wire, Particularly Wire for Ropes," which gives the result of research work undertaken with the view of ascertaining the correct heat treatment of wire. The following is an extract of his conclusions:

It will be seen that a somewhat simple method has been reached whereby a manufacturer can determine the correct amount of carbon which his steel should contain to produce a certain maximum stress in the finished wire; and at what point the process of reduction should cease, so as to get the most useful amount of work out of the finished rope.

Further, the experiments show that it is possible to increase the specific gravity of steel from 7.768 to 7.998 by cold working, and that when it reaches this point and is again subjected to a crushing action by pulling through a die, as in wire-drawing, it actually gets lighter, showing that it is impossible by this means to make it more dense.

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It must be borne in mind that the results here given probably will not apply to steel made by different processes and of different chemical compositions.

Further, the results show that the usual methods of obtaining the best wire by means of torsion and tensile tests are not altogether trustworthy for determining the best point for the wire to perform useful work.

50. For winding ropes on the Rand, manufacturers recommend steel wire of an ultimate stress of 105 to 135 short tons,* and it appears that 120-ton steel is most commonly used. The lower and higher limits are advised for working conditions, as regards bending stresses, either unfavorable or very favorable. There are cases in which 150-ton material has given quite satisfactory results.

51. The experiments with nickel steel and vanadium steel for winding ropes have not proved successful, and no manufacturer appears to be able to recommend these alloys.

52. The effect of galvanizing "plow" steel wire and the amount of protection which this treatment affords, even when some of the coating has been broken, has been investigated locally by Mr. W. M. Epton and Dr. Moir. Their experiments go to prove that: (1) the ultimate tensile strength is not lowered, while the elongation is doubled; (2) the capacity to resist torsion is reduced 20%; (3) the capacity to resist bending is reduced 25%.

The protecting power of galvanizing, even when the surface of the steel is not wholly covered as would be the case in a worn winding rope, is shown in a table presented by Mr. Epton and printed on page 167 of the Minutes of Evidence. The corrosion of partly-galvanized wire proved to be only about one-eighth of that of plain wire with the same surface exposed. It must be stated, however, that the wires experimented with were not of the ordinary commercial quality, as the experimenters prepared their own samples by dipping.

53. With respect to galvanized winding ropes, opinions are divided; but the weight of evidence is against using them. Galvanized ropes have given good results in wet upcast shafts; but if the water is acidulous, it is stated

*Unless otherwise specified, all "tons" referred to in this report are tons of 2,000 lbs. each.

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that brittleness may result in the wire owing to galvanic action and the formation of hydrogen. Experiments carried out in the Mines Department Chemical and Mechanical Laboratories, however, go to disprove this contention.

54. The following extract and table are taken from the proceedings of The Transvaal Institute of Mechanical Engineers, March 10, 1906:

The authors are more than glad that they had the temerity in their paper to introduce the chemical aspect of rope deterioration. No misconception appears to have arisen owing to the step—the chemists have come forward with alacrity to assist in the inquiry, and they have attacked each other, and not the writers.

The interesting experiments of Mr. Heymann go to show that even the most acid mine water has very little more corrosive action than plain water, and that the primary cause of the corrosion of the wires of winding ropes is contact with air or deleterious gases. This is a most impotant point, in that it allows of experience gained in Great Britain with respect to the efficiency of galvanized wire rope to be referred as holding true for the Transvaal. Dr. Moir's experiments have entirely disposed of that bogey, which was always a scientific fallacy, viz., that during the life of a galvanized wire rope, when the zinc was worn off in places the galvanic action would then lead to more rapid wasting of the steel.

Through the courtesy of Messrs. Allen, White & Co., Dr. Moir and the writers have been able to repeat the experiments, the results of which were previously published, dealing with the effects of galvanizing as a preservative and as a deteriorating agent with respect to the ductility of the steel. The samples forwarded represented identically the same wire, plain and galvanized, so that an exact comparison was possible.

The accompanying table shows the results obtained. The method of preparation of the specimens for the chemical test was the same as previously described by Dr. Moir. It is evident that a coating of zinc has a protective action on steel, even when the latter is exposed to the acid. Generalizing, results show that plain wire suffers about 30 times as much corrosion from fairly strong acid as the same wire does when it has a coating of zinc near the exposed surface of the iron, and about ten times when the acid is weak.

The galvanizing in these instances was, of course, of the ordinary commercial character, and not home made as in the case of the previous experiments; the reason for repeating the tests being that the latter improvised method of galvanizing had, it was suggested, possibly spoiled the wire.

The effect on the ductility, and on the other desirable qualities that the hard-drawn steel originally possessed, is fairly clearly set forth in the tabulated results. The

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elongation is increased nearly 100%; while the tensions and bendings obtained are reduced, the former rather less and the latter in a rather greater degee than was anticipated from the results recorded by previous investigators.

The difference in tensile strength between galvanized and non-galvanized wires amounted to only a very small percentage. If you take the actual area of the wire, counting in the thin coating of from 0.001 in. to 0.002 in. of zinc on the outside, it shows really a moderate reduction in tensile strength; but where you figure it on the actual area of the steel there is really no appreciable reduction. The figures are a bit variable. We obtained in one case 1,200 lbs., as against 1,220, the breaking load of the wire—the 1,200 being ungalvanized and the 1,220 galvanized. The makers at home get 1,210 and 1,215. Unfortunately, Mr. Epton, who actually carried out the tests, is away; but I am certain of this, that he was convinced in his own mind that there was practically no reduction in tensile strength at all.

55. The Commission considers galvanized wire ropes worthy of trial in cases where ordinary ropes suffer rapid corrosion.

Winding Ropes (Preservation).

56. All evidence goes to show that the preservative treatment of a rope during its manufacture is a matter of the highest importance, and has a considerable influence on the life of the rope. The core, of tarred Russian hemp, should be thoroughly soaked in an acid-free lubricant. The wires should also be well lubricated while they are being "laid-up," and the whole rope then, if the dressing is sufficiently thick and heavy, is well prepared to resist the corrosive action of a damp atmosphere. For shipment abroad, ropes are usually coated with a black (plumbago) varnish; such a rope should be well treated with a lubricating dressing before being put to work, and this is a wise plan to adopt with all winding ropes.

57. Regarding the composition of a suitable dressing, there are several recipes put forward. Most manufacturers favor plumbago, or graphite mixed with vaseline, linseed oil, palm or other vegetable oil. Three riggers, who gave evidence, differed entirely on this point; one favored Stockholm tar with grease, a most objectionable compound; another favored a mixture of one part cylinder oil to two parts of truck grease, while the third was in the habit of using a patent composition.

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58. A table from Messrs. Vaughan and Epton's paper, giving in condensed form information relative to various rope, dressings, is given in this connection.

59. The following extract from the "Queensland Government Mining Journal" of January, 1907, is quoted here as being a clear instance of a rope having been ruined through the use of an unsuitable lubricating dressing:

Recently the manager of the Bluff Colliery, Central District, who had experienced difficulty through breakages in the wire rope in use at the mine, forwarded to Brisbane a sample of the water, which he considered the cause of deterioration in the rope. He mentioned that the lubricant used was Stockholm tar, tallow, and resin. At his request, the Mines Department had the water analyzed, and the report of the Government Analyst (Mr. J. Brownlie Henderson) on the subject is as follows:

"I have the honor to report that the sample of water received from you contains no free acid, except the carbonic acid present in all natural waters. I do not think it is necessary to look for the cause of corrosion in the mine water. The lubricant used for the rope is undoubtedly the cause, and a more objectionable lubricant than the mixture of Stockholm tar, tallow and resin which was used, either from a physical or chemical standpoint, could hardly have been applied. Stockholm tar always contains acetic acid, and I recently had a sample which contained nearly 10% acetic acid. Tallow readily becomes rancid, and then contains free organic acids. Resin is mainly an organic acid. The Stockholm tar is the worst ingredient, and it alone would soon destroy any wire rope."

60. It should be pointed out that if a rope dressing is used which hardens on exposure to the atmosphere, care should be exercised to see that the pit-head sheave is kept cleaned out in the groove of the rim, as it has been proved by more than one accident that the winding rope can be thrown off the sheave by reason of accumulation of hardened lubricant in the tread.

61. Mr. A. McArthur Johnston, Metallurgical Chemist of the Consolidated Gold Fields of South Africa, Ltd., gave the following results of analyses of several rope dressings:

Dressing No. 1.—Acidity equivalent to 0.19% sulphuric acid.

Dressing No. 2.—Acidity equivalent to 0.21% sulphuric acid.

Dressing No. 3.—Contains traces of alkalinity.

Dressing No. 4.—Acidity, traces (less than 0.01% sulphuric acid).

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Dressing No. 5.—Acidity equivalent to 0.30% sulphuric acid (of this acidity, mineral acid accounts for 0.11% sulphuric acid). This preservative also contains finely divided graphite substance.

Dressing No. 6.—This would seem to be petroleum jelly (vaseline), flavored with a little nitro-benzine. It is free from mineral acids.

62. It is obviously desirable that rope dressings should be free from acidity, and, from the quoted results of tests, it appears absolutely necessary that tests should be made from time to time *by qualified persons* to see that this freedom exists.

63. A good rope dressing wards off corrosion and reduces frictional wear. It should be applied every fortnight in dry, or nearly dry, vertical shafts, but more frequently in inclined shafts on account of its being rubbed off by friction sooner. In wet shafts the dressing should be applied weekly, or even oftener if found to be necessary from the condition of the rope. The dressing should be applied hot to the cleaned rope, by slowly passing the latter through a box containing the composition. Mr. J. M. Wright exhibited a model of a mechanical rope-cleaning and oiling machine, but no opportunity offered to try the device under working conditions. A simple machine should certainly tend to secure the regular and thorough cleaning and dressing of the winding ropes. Mr. J. B. Pitchford, in a contribution to the evidence, states:

In order to make a proper examination of a rope, it is necessary to clean it properly and remove all the tar, etc., from the wires, leaving them as bright as possible. One method of doing this is to pass the rope through a trough of hot oil, which removes all the tar. The trough is made of steel, and can be from 15 ft. to 30 ft. long. It is of "U" shape in section, and has a steam space of 1¼ or 1½ ins. around the bottom and sides. It is fitted with a relief valve and a drain, so that the condensation can be taken to the hot-well.

The trough is filled with oil and heated, and the rope to be cleaned is passed slowly through it under depression pulleys, by being wound from one rope drum to another. By providing two sets of rope-handling engines, the rope can be passed back and forth through the oil until it is quite clean enough for examination. The rope-drum engines are so arranged that they can wind the rope over the headgear sheaves from either of the winding engines. The drums can be moved on the shaft to bring them in approximate alinement. By having a spare rope, the work in a shaft need not be detained

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for rope examination, the only time required being that necessary to unwind one rope and to put on another. Similar arrangements to these were used a number of years ago at Virginia City, Nevada, where flat ropes were used extensively.

64. With reference to the possible deleterious effect of working conditions on the life of the rope, one manufacturer remarks:

A winding rope, made to suit the special winding apparatus at a mine, should depend only upon the number of foot-pounds of work done for its life. The more material lifted from the mine, or the quicker that it is lifted, has a factor upon these foot-pounds in direct proportion to the life of the rope.*

While the statement is doubtless theoretically correct, it has been found in local experience that practical difficulties exist in the manufacture of a winding rope that will absolutely suit special working conditions. There may be a combination of adverse factors such that any provision made to combat the one only tends to weaken the defense of the other. For instance, in a compound shaft (partly vertical and partly inclined), the large frictional wear due to the guide-sheaves in the bend and the rollers on the incline naturally point to the use of large outer wires in the strands of the rope; but if the winding drum is of small diameter, the maker might well hesitate to do this. Speaking broadly, it may be said of winding ropes on the Rand that the working conditions have such an effect on their lives that comparison in respect to the duty of the rope is seldom attempted, except, of course, in the cases of ropes which follow one another on the same winding plant.

65. It is quite usual for the rope to be wound in several layers on the drum, especially in the cases of some of the older winding plants which are now being used for considerably greater depths than those for which they were designed. Where heavy loads are hoisted, and the smaller diameter of the drum leads to the use of ropes of compound construction, there occurs very severe and rapid wear on the rope, due to crushing and pinching actions. In several such cases it has been found that a

*This last sentence, a trifle obscure, is evidently intended to say: "The amount of material lifted, and the rapidity with which it is lifted, are the factors which determine the life of the rope."—Ed. Eng. News.

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rope of "best crucible" steel of about 100 tons breaking stress proves to be the longest-lived, although it is more unfavorably conditioned with respect to statical loading and bending stress than the ropes of other constructions.

66. Variation in the direction of shaft also introduces a very destructive influence. Of the shafts on these fields in which raising and lowering of persons is permitted, there are 89 vertical, 56 inclined, and 84 compound. The compound shafts are, in nearly every case, graded vertical to inclined, and the turn is made on a bend of fairly large radius, varying from 50 ft. to 170 ft., and, in some cases, even up to 600 ft. The rope in going around the bend is guided by a series of seven or eight wide rollers. These rollers, to minimize inertia effects, are generally made up of a series of narrow, flat-rimmed sheaves, threaded on the same spindle with designedly but slight clearance between adjacent sheaves. Inertia troubles, however, are never got rid of completely, and the spacing of the sheaves widens with wear, and has been known to allow the strands of the rope to be pinched between the rims.

67. The rollers on the inclines are not always moving freely, and the gritty dust that hinders their successful operation also causes the rapid wearing away of the wires of the rope. While this wear is evenly distributed over the circumference of the rope, it is not nearly so dangerous as when it occurs, as it sometimes does, near the attachment to the skip, in a one-sided manner, perhaps nearly severing an individual strand of the rope. Uneven deterioration in one particular part of a winding rope is a particularly dangerous defect, as the equal distribution of the load among the component wires is disturbed, and the danger of actual fracture is more nearly approached.

68. The rollers should be of the lightest possible design, well balanced, and of sufficient size to prevent excessive speed on the wearing spindles. No matter how well designed, they still have the effect of shortening the life of the rope, as it is impossible to keep them always in the best working condition, owing to grit, acid water, etc. This no doubt accounts to some extent for the shorter life of many of the winding ropes in inclined shafts on the Witwatersrand, as compared with ropes

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working in the vertical shafts of coal mines, where such severe conditions do not obtain.

69. Evidence was taken as to the advantage or disadvantage of using rests (keps) to facilitate the loading of the conveyance. Nearly all the witnesses were opposed to the use of keps, although acknowledging that they are probably necessary where a cage is used and truck loading is in vogue—especially so in the case of deep winding. Up to the present they have not been proved necessary for skip loading, even in very deep shafts. On the majority of the Witwatersrand mines they are certainly not necessary, and, if installed, would constitute a source of danger if used anywhere else in a shaft than at the lowest loading stations. Apart from any such danger, the general objection to the use of keps is that they shorten the life of the rope by introducing more severe alternation of the loading of the rope than is necessary, and lead to a pick-up shock which is greater than the shock of loading with the rope hanging taut. They are not recommended, therefore, as their use increases the risk of accident and they are harmful to the rope.

70. With reference to the question as to how far the rope is affected by the speed at which hoisting is carried out, rapid winding is considered to be the more harsh condition; and the opinion was expressed by several witnesses that slow winding with big loads will give longer life to the rope than quick winding with small loads. This is not on account of the fact that the average speed is higher in one case than the other, but because of the existence of a greater liability to shocks due to sudden changes of velocity.

71. In order to minimise the bad effects of rapid winding on the rope, it is necessary to have the pit-head sheave as light as possible and the winding drum massive, so as to moderate the shocks in starting and stopping. With a heavy sheave there is a tendency to wear the ropes very severely at the points of acceleration and retardation, owing to the ropes skidding when the velocity of winding changes quickly. In a well-designed winding plant it should be possible, with careful driving and good governing, to avoid sudden large alterations of speed. A good speed indicator, such as a recording tachometer,

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is likely to conduce materially to the smooth running of the cages, both from the assistance it gives to the engine-driver and from the check that it provides on the manner in which he performs his duty.

72. Where small winding drums are used to carry several layers of rope, very severe damage is frequently caused owing to the "pinching" effects that occur at the cheeks (flanges) of the drum, where the winding rope is forced by wedge action to turn backward on itself in a riding turn. This can be obviated if the flanges are constructed to a design introduced by Mr. H. C. Behr, Consulting Mechanical Engineer to the Consolidated Gold Fields of South Africa, Ltd. In his standard specification for winding engines, as mentioned in Mr. E. J. Laschinger's evidence, it is provided that:

"The last groove opposite to where the rope is attached shall rise gradually above the other grooves, so as to raise the second layer of the rope gradually, and without shock, above the first layer. In order to prevent overstraining the drum flange, or wedging the rope as it mounts from the second to the third layer, where it cannot be assisted by a rising groove in the drum as employed in the case of mounting the rope from the first to the second layer, the drum flange at that point shall be formed with an annular projection sloping at an angle of 45° for the depth of the second layer of rope. Below the sloping part there must be a filling piece shaped along a spiral, so as to fill the space between the edge of the rope and the lower edge of the conical projection of the drum flange, for the purpose of preventing the end of the second layer of rope from being wedged in between the first layer and the foot of the flange."

73. Side friction of one coil of rope on the next coil, as also on the lower coils on which it is bedding, may be produced by too short a lead from the pit-head sheave to the drum. The angularity of the pit-head sheave and the horizontal distance of the drum from the shaft should so conform to the width of the drum that the deviation of the rope is not too great. An angle of 2° on each side of the center line has been found to be sufficient. If this limit is departed from to any extent, there is considerable side friction on the rope, and the coiling of the rope on the drum is likely to give trouble. However, in the case of a grooved drum with the rope coiling in only one layer, it may be permissible to have more lateral deviation.

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74. Practically all the evidence tendered was in favor of the view that periodical re-capping materially increases the life of a winding rope, from 10% to 30% being the estimates of the gain resulting from the regular practice. Each time ten or twelve feet are cut off from the lower end, the whole working part of the rope is shifted that amount towards the conveyance, and the positions of greatest wear are thereby altered—with the exception, however, that any local damage that exists in the rope due to "pinching" at the flanges of the drum, is not prevented from increasing. To change the wear from these places, it is necessary to alter the position of the attachment of the drum end of the rope, or to slack out this end should there be spare rope carried inside the drum.

Winding Ropes (Examination).

75. The absolute necessity for a daily examination of each winding rope by a competent person is a point on which all witnesses agree. The Commission also recommends a weekly examination on the following lines:

76. The person making the examination stands in a safe position at the collar of the shaft and allows the rope to be slowly raised or lowered through his hand, which is protected by a thick glove or piece of waste. The rope should not be moved faster than forty or fifty feet per minute; and, while feeling with the hand for any broken wires, the eye of the operator watches closely for any other defects, such as excessive wear, loosening of the strands, straightening of the lay, kinking or severe corrosion. When anything abnormal is noticed, the motion of the rope should be stopped and the suspected part thoroughly cleaned and examined. If the defect is a serious one, such as the occurrence of two or more broken wires in a short length of the rope, say two feet, the engineer's attention should at once be called to the fact; while, in the case of a lesser defect, a note should be made of its position in the rope, a proper entry logged in the record book, and the engineer duly informed. It is also advisable that the rope should be watched for a short time while it winds on and off the drum and while coiled on the drum, so that the positions of possible pinching or crushing can be located and examined.

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77. A few of the witnesses were of the opinion that the daily examination of the ropes was not regularly or properly carried out, and others spoke of the difficulty in finding time for it. There appear to be difficulties in the way of setting apart a particular time of the day in which the rigger or other person detailed for the work, shall have the rope and winding plant at his disposal. This Commission, however, feels strongly that the regulation which provides for the daily examination of the ropes that raise or lower persons should be enforced with the utmost stringency. The withholding of facilities for the carrying out of this examination should constitute an offense against the regulations, while, on the other hand, the penalty for making a false entry in the record book should be most severe.

78. The proposal was made to the Commission by the three riggers who gave evidence, that the rigger (or wire splicer) who carries out the daily examination, and who, under the supervision of the mechanical engineer, has sole charge of the winding ropes, should be certificated: that is to say, he should pass a practical examination under Government ægis to ensure his competency. The Commission has not not gone deeply into this question, but regards it as one worthy of the serious consideration of the Government. It has to be noted, however, in this connection that the mechanical engineer, who is responsible under the Regulations for the monthly examination of the rope, in accordance with recent amendments,* has to be the holder of a certificate of competency. In the Syllabus of Subjects comprised in the Examination Scheme, "Wire Ropes—their Structure, Inspection, and Maintenance," finds a place. So that it appears probable that this member of the staff of the mine, who actually engages and supervises the rigger, will be quite able to decide as to his competency or otherwise.

79. A good deal of evidence was given in favor of making the "thorough" examination of the rope a weekly duty, as contrasted with the present monthly practice. This proposed alteration of the regulations is not recommended by the Commission, the necessity for the change not being considered to be established. The monthly

*See Section 1, Mining Certificates Amendment Ordinance, 1906. Government Notice No. 1232 of 1906.

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examination appears to be designed for the purpose of carefully gaging the progress of normal wear and assessing the probable strength remaining in the rope, while the daily examination is emphasized in importance as being the one which is relied upon, and that practically entirely for the detection of abnormal and unforeseen deterioration. The functions of the two examinations, although related, are very far from similar.

80. When a rope has been working for some months, or when there are signs of rapid deterioration, the engineer will naturally make his thorough examination more frequently—every fortnight, or even once a week. This contingency appears to be anticipated in the regulation which reads "At least once a month, etc."*

81. To clean a rope for thorough examination, certain mechanical devices were suggested, the idea being in each case to pass the rope through a box containing scrapers or revolving brushes. In one case a trough of boiling oil was suggested. These devices have been alluded to in paragraph 68 of this report.

Most persons appear to consider it unnecessary to clean the whole rope thoroughly, and it is doubtless quite sufficient for the purpose of even thorough examination to clean the rope at selected places by means of the usual appliances, viz., a stiff wire brush and paraffin or oil, according to the preservative composition used on the rope.

82. The portions of a rope that should be most carefully examined will generally be well known to the mechanical engineer from his experience with preceding ropes, and the knowledge of why and where they deteriorated most. With respect to external wear, the places in the rope that should be especially watched are those where contact with the pit-head sheaves or heavy guide pulleys occurs at acceleration or retardation periods of the hoist. These places are also likely to suffer more than any others from internal wear, excepting perhaps that portion of the rope near the skip or cage, which, although generally subjected to no rubbing wear, yet is exposed to the corrosive effects as well as to the bending and shock stresses. In addition to these positions, at-

*Extracts from the Mining Regulations of the Transvaal will be found on pages 78 to 88.

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tention must also be directed to that part of the rope which lies between the drum and the sheave when the load is at the bottom of the shaft, as also to those parts of the rope which come in contact with the flanges of the drum.

83. On p. 170 of the oral evidence are given particulars of the tests of three worn ropes. These ropes had been discarded by the mine authorities, and it was there-

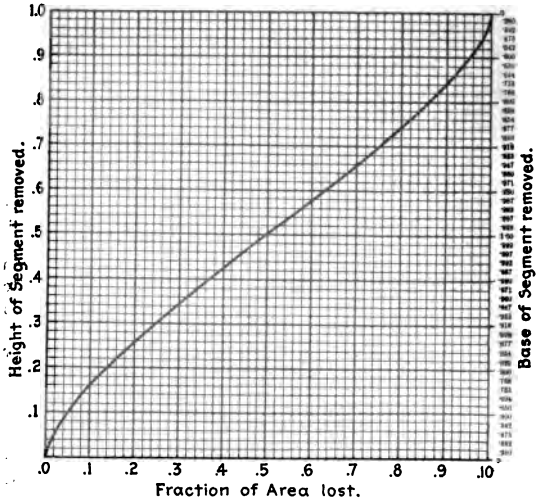

Diagram for Graphical Estimation of Reduction in Size of Cable Wires Due to Wear.
(See Paragraph 84 of Report.)

fore possible to cut them up and obtain samples showing the condition of the rope at various points. One of these ropes, the original breaking strain of which was 62.5 tons, broke at loads varying from 46.1 tons to 47.9 tons. This rope had only been in service 7½ months, and was discarded owing to a bad kink. Another similar but longer rope broke in various places at loads ranging from 36.0 to 53.8 tons. The third rope, of 1½-in. diameter and

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originally of 105 tons breaking load, broke at loads varying from 74 to 89 tons. The results of these tests bear out what has been said previously regarding the positions of probable maximum deterioration.

84. Opinions are equally divided as to the necessity of relieving the rope from the stress of its load during the examination. For taking circumferential measurements at various positions on the rope, so as to compare wear, it is certainly not desirable; but for the purpose of internal examination it is absolutely necessary. Slack strands or wires, or straightening of the lay, where such occur, can generally be seen under ordinary working conditions. With respect to the calculation of wear by means of circumferential measurement, the following extract from Messrs. Vaughan and Epton's treatise may be quoted:

In estimating the reduction of the size of any wire due to wear, the accompanying diagram may be of some assistance. This diagram shows the fractional area of circle remaining after a segment of known base and known height has been removed. Taking the diameter of the circle as unity, there are for each value of the base two values for the height, one greater than 0.5 and one less than 0.5. There should, however, be no uncertainty or error due to this cause, as it is a fairly easy matter to see whether a wire is half used through or not. The length of the base of the segment worn away can be measured by one person examining the rope after the removal of any side "burrs."

To estimate the height of the segment worn away in a portion of the rope which is fairly uniformly worn, the writers advise a comparison of the circumference of the rope at this place with the circumference at some other place at either end of the rope where there is little or no surface wear, while at the same time there is some reduction in size of the rope due to untwisting and stretching under the working load.

To measure these circumferences, wrap a fine wire or unstretching cord ten times around the rope in each case. Dividing each measurement by 10, the true circumferences are found, from which, by reference to tables, the diameters of the rope at the two places under comparison may be arrived at. Subtraction of these diameters should give approximately twice the height of the segment of wire removed by wear.

If the approximation is nearly correct, and if the base of the segment has been correctly measured, these two values, height and base, must lie at the ends of the same horizontal line in the diagram. If they do not, there is some error and one must try again. If they do, the point where this horizontal line cuts the curve in-

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dicates the fraction of circle remaining and also the fraction that has been worn away.

85. Dealing now with methods of assessing the deterioration of a worn rope, other than by the examination of the separate wires of a piece cut from the end at the time of re-capping, it appears correct, in the case of a rope of simple construction, such as 6.6.1, to state that if the wear evident externally is taken into consideration—neglecting the deterioration that may possibly exist internally—a fair idea of the strength of the rope will be arrived at. If, however, corrosion is to any appreciable extent visible externally, it will be wise to assume that it also exists on those parts of the wires which cannot be seen.

In a rope of compound construction, the possible condition of the internal wires has to be considered, and this makes the calculation more difficult and naturally more of the nature of a guess. A point of possible assistance is the fact that in a rope of this description, when the internal wires are corroded, this generally has the effect of loosening the strand somewhat, and the outer wires are "standing up," or probably can be raised up or pushed aside so that the condition of the inside wires can be seen.

86. Most witnesses agree that internal wear or corrosion is very difficult to discover, but some suggest that by untwisting the rope slightly the condition of the wires on the underside of the strand can be seen. This can be done by means of two twitches and levers, and it is maintained that the strands of the rope can be closed into their normal positions again without injury. Several witnesses were strongly adverse to this opening out of the rope, and it appears fairly certain, in the case of a well-worn rope, that the strands would not naturally return to their places. It stands, therefore, as a procedure not to be recommended except in exceptional cases, where internal corrosion is known to exist and must be gaged and where the user of the rope is prepared to discard it if damage is occasioned thereby.

The use of a marlin spike was also advocated by one or two practical witnesses, to open up the rope for internal examination. While it is possible that in the hands of a wire splicer of large experience this method

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might be safe, the great possibilities of dangerous damage being done to the rope by a less skilled person absolutely condemn what, it is trusted, is not a practice.

Winding Ropes (Best Method of Testing).

87. In dealing with the important matter of how best to ascertain the true strength of a new rope, the weight of evidence is in favor of a tensile test to destruction of a sample of the whole rope. It is true that some manufacturers state that the true breaking load can be calculated from the aggregate strength of the wires; but there still exists a considerable diversity of opinion among these experts as to the percentage reduction that should be made from this total to take account of the fact that the wires, when laid up in the form of rope, are not in a position to give out their full efficiency. One manufacturer advises a deduction of 8½%, while others state 10% to 12%. There is also a lack of agreement as to whether or not these deductions should vary according to the construction of the rope. As a practical acknowledgment of the inaccuracy of these assessments for use generally, it is found that the majority of the manufacturers who export ropes to the Transvaal prefer to give the strength of the rope as the aggregate of the strength of its wires, and allow the purchaser to make any deduction he may think proper.

88. Mr. Epton, after a large number of tests of new ropes of various manufacture and construction, found that a difference of from 3% to 16% existed between the aggregate strength of the wires and the breaking load of the rope. Thinking that this loss of efficiency might disappear after the rope had been well tightened in the course of a few weeks' use, some further tests were made under these conditions. The results point to the fact that this efficiency is not regained.

89. Seeing that it is highly desirable in the interests of safety that the real breaking load of a new rope should be known in preference to the theoretical utilimate strength, the Commission is led to the conclusion that the only correct method is to test a whole sample of each new rope before it is put into use; that is to say, each new rope should be delivered to the purchaser

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accompanied by a test certificate which, if not obtained in the country of origin, should be procured from the Government Testing House in the Transvaal, duplicate certificates being allowed for separate portions of the same coil.

90. As to the length of rope required for such a test, opinions vary; some witnesses saying that a length of two feet is sufficient, while others consider that it is necessary to use at least ten feet; but from experiments made in the Transvaal Mines Department Mechanical Laboratory, very little difference appears to exist even in these limiting cases. The results of comparative tests between long and short samples of two ordinary winding ropes have been made public by Mr. Epton. In one case there was practically no difference; and in the other case, in which a length of 4 ft. 4 ins. was compared with a length of 14 ft. 10 ins., a difference of 900 lbs. in 50 tons was found, this being in favor of the short test length.

91. Several different methods of holding the whole rope specimen during test appear to be in vogue, but the best and most frequently used in public test houses is to open out, clean and tin the wire, and then run on a soft, white-metal conical seal. In the Mines Department Laboratory it is the practice to use an ordinary commercial white metal which has a melting point of about 375° F., and which has been found not to damage the wires in the least degree.

92. It is considered a proper practice to apply to the individual wires of a rope other standard tests, such as tension, torsion and bending tests. These are very useful to mark down a very inferior wire, or to show up large departures from uniformity.

93. To determine the strength of a winding rope during its working life, the evidence taken appears to show that the best method is to re-cap the rope at intervals of from three to six months, and to have a portion of the rope cut off for testing purposes. It is also strongly advised to examine the wires thoroughly at the same time, by means of a magnifying glass or microscope, for corrosion or any other deteriorating influence. It would be more correct to make the interval between successive re-cappings dependent on the duty of the rope, but this

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course is obviously impracticable. The mining regulations of the Transvaal provide for regular re-capping, not more than six months being allowed to elapse between successive re-cappings in the case of a round rope, nor three months in the case of a flat rope.

A portion of the rope cut off, in length not less than half the circumference of the pit-head sheave, must be sent to the Government Mechanical Laboratory for testing. The practice followed in the laboratory is to furnish a certificate of the actual breaking load of the specimen, and at the same time to call the attention of the mine manager to any defects, such as brittleness, corrosion, want of lubrication, etc. This practice is in every way commendable, but we would recommend that the six-months' period should apply also to flat ropes, which are no more difficult to examine than round ropes.

94. A question was asked in Schedule 2 with reference to the utility of an elongation test of the whole rope, from time to time, during its working life. Opinions seem to be about equally divided on this point. Some witnesses think it would be an advantage at stated intervals to ascertain the stretching power of the rope when hanging in the shaft, by applying its usual working load or something in excess of this. Others think that no useful purpose would be served and that certainly loading in excess of the normal conditions might do damage.

95. Professor Joseph Hrabak, of Pribram, carried out some interesting experiments to determine the elongation of wire ropes under known loads, and thus to find out the modulus of elasticity. He refers fully to these in his book "Die Drahtseile," and from the description of his tests it appears that the data were arrived at by loading the cage with men in many deep-level vertical shafts, and noting the elongation thus produced in the rope. In a 3,000-ft. shaft the elongation amounted to about one inch per man, and it is therefore possible to measure it reliably and accurately. The modulus of elasticity of a winding rope will vary during its working life, being small at first, and afterwards increasing to something nearer the value of the modulus of the wire itself; and then, if the rope is kept in use long enough, it will probably decrease. This last effect, if observed, is to be

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taken as a danger signal, pointing to the deterioration of the rope.

96. On the whole, the Commission considers that the practice of making elongation tests of the whole rope is to be recommended, but that the ordinary working load would not be exceeded to more than the extent of doubling the authorized load of the skip or cage.

97. It is also strongly recommended that when a winding rope is taken off, and its life considered ended for the particular purpose for which it was installed, a sample from the most worn place should be tested. The results of these tests should prove of the greatest service to the person who has had charge of the rope, as they would enable him to see how far his judgment was sound concerning its condition. It is not recommended that this practice should be made compulsory, for the reason that it would probably involve in most cases the wrecking of any utility that the rope might still possess for purposes other than that of transporting persons.

98. A very important question arises in this section of the Commission's investigations, as to what loss of strength a rope has sustained owing to the removal by friction, etc., of a certain definite proportion of the cross-sectional area of the wires. To come to any sound conclusion regarding this matter, it is necessary to know what support is afforded to any individual wire by the gripping tendency of the adjacent wires. Mr. Epton, in his evidence, submitted the results of tests conducted by him of two rope samples, 26 ins. in length between the grips, each specially prepared by having ten of the outside wires cut through. These tests showed that the supporting effect of the sound wires on the broken wires amounted practically to nothing. These rope samples were new or only slightly worn.

99. Of 91 complete tests of worn ropes carried out in the Mines Department Mechanical Laboratory, 33 show that the laid-up wires have a greater strength than when tested individually at the most worn part, and 49 show the opposite, while 8 give almost the same results, whether tested as separate wires or in form of a rope.

It is interesting to note that the great majority of the ropes which tested higher than the aggregate of their wires were of the simple construction, viz., six strands

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of seven wire, 66.1. All these results go to show that in a short length of rope—two or three feet—the strength of the rope cannot fairly be assumed to amount to more than the aggregate strength of the wires, estimated in each case at the position of greatest wear, although these positions may not all occur at exactly the same point in the rope.

Mr. Epton stated that in only 5 cases out of over 400 had he found ropes to break at a much lower load than was estimated from external appearances, the estimation having been made by assuming that there was no lateral support between adjacent wires. In these cases there were excessive internal corrosion and wear, and the first-named defect would probably have been quite as pronounced in a sample cut off from the end of the rope.

Factor of Safety.

100. The Commission has carefully considered this important matter, and recommends that the present Regulation which provides for a factor of safety of 6 as a minimum during the life of a rope should be adhered to. No reliable statistics were brought forward by any witness, and none were otherwise available, dealing with the working of winding ropes at a lower factor of safety than 6; and the Commission is of the opinion that considerable experience should be obtained with ropes working at lower factors while hoisting mineral, before any departure could be recommended for the Transvaal practice, which has been found to be satisfactory.

101. The breaking of a winding rope while raising or lowering persons happens very rarely, and since mining was re-started on the Rand in 1901 there have only been two such occurrences—this is neglecting an accident which occurred at a mine where 23 persons were killed owing to a rope in good condition being cut in two while lowering the cage, by a projecting bolt in the flange of the drum. Although causing great loss of life—in one accident 44 and in the other 26 persons were killed—it must be recorded that in each of these two cases the rope had been allowed to deteriorate until the factor of safety was far below 6, the persons

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charged with the responsibility of examining these ropes having failed to detect this. These statistics, as well as others concerning ropes that have been broken when no persons were traveling (see paragraph 143 of this Report), satisfy the Commission that a minimum factor of safety of 6 is sufficient.

102. Mr. E. J. Laschinger in his evidence stated that, considering the great variations to be met with in the design of engine details and in the general arrangement of the winding plant, it should be permissible, especially in deep shafts, to make allowance, in fixing the factor of safety, for special attention paid to the design of the plant which has for its object the ensuring of best working conditions and the safety of persons traveling in the shafts. Mr. W. S. Thomas also favored this idea and agreed that, after a certain critical depth, there was good reason to believe that safety might be assured by the maintenance of a stated reserve of strength in the rope, considering that there were many deteriorating influences, such as shocks due to sudden changes in velocity of winding, which did not increase with depth.

103. Mr. W. A. Kincaid considered that there was additional safety in a long rope, and that for this reason is was not necessary to carry as high a factor as with a short rope—other conditions being the same. There had been cases at the mine he was managing where, owing to the jamming of the conveyance, which involved great resistance to the upward winding, great damage had been done to the timbers; yet the rope did not break, owing, in his opinion, to its being of great length.

104. Other witnesses, especially those acquainted with British colliery practice, advocated factors of safety as high as 10; but there appears to have been some misunderstanding as to whether these were to apply to ropes newly put on, or to ropes that had been some time in service. A careful review of the evidence, however, makes it clear that initial conditions were referred to.

105. The Mining Regulations of The Transvaal, when laying down the minimum factor of safety, deal with the winding rope at work and not when about to be put on the drum; and the Commission is convinced that this is the correct attitude to take up, while recognizing the

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difficulties that stand in the way of correctly estimating the strength remaining in a worn rope.

106. There has been no suggestion throughout the whole of the inquiry that the mine authorities have ever hesitated, on the ground of expense or for any other consideration, to discard a winding rope so far as the transport of persons was concerned, when advised professionally to do so. The practice on the Rand is in point of fact quite the reverse of this, and the greatest caution is displayed in this respect to secure the safety of miners. The few errors that have been made have been due to the carelessness or faulty judgment of the persons responsible for the examination of the ropes.

107. In deep-level winding, from 4,000 ft. and over, it is practically impossible to start off with a static factor of safety of more than 7 in the rope. When reduced by wear to a factor of safety of 6, and about to be discarded after possibly no more than six months' work, this rope will still have an enormous reserve of strength, considering static conditions only. Quoting from a paper read before the South African Association of Engineers in March, 1904:

> Imagine for a moment that similar loads of, say, 7 tons each—consisting of 6,000 lbs. conveyance and 8,000 lbs. contents—have to be hoisted from two shafts, one of 1,500 ft. and the other of 6,000 ft. in depth. Supposing the ropes used in these two instances are of the same grade of steel (120 tons per sq. in.), then, if they are compared at a time when they each have the minimum factor of safety of 6, it will be found that the reserve of strength in the case of the 6,000-ft. rope is approximately 2½ times that existing in the 1,500-ft. rope. The latter, when the full skip is at the bottom of the shaft, will be loaded to within, say, 45 tons of its breaking load, while the former retains a margin of about 110 tons.

108. In this paper it was also proved that the shocks due to jerks or sudden changes of velocity were dangerous, practically, only to a short rope; and that after a depth of about 1,500 ft. had been reached, the shock due to any specific change of velocity would remain constant.

109. The Commission was, however, unable to take full advantage of the results of this research and to advise a reduction of the minimum factor of safety for

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deep-level winding, because it was felt that there were other stresses in the rope that had neither been exactly determined nor proved to be independent of the depth of winding. The stress due to bending is probably the most important of these, and much experimental research is needed to discover how far the flexibility of the rope, and at the same time the bending stress in its wires, is influenced by the closer packing of these which the use of a lower factor of safety would involve.

110. A correct determination of the bending stress in the wires of a rope will be of the greatest value, and, if this can be shown to be much less than it has been assessed by Professor Hrabak and other investigators, there will then be good reason to reconsider the decision now arrived at, viz., that the minimum factor of safety of 6 shall be retained.

111. Evidence was given to the effect that hardship was caused by the present Regulation* which prescribes that, "in case a winding rope is used for other purposes besides the transport of persons, the maximum working load, when raising or lowering persons, shall not exceed 0.85 of the maximum load when the rope is in use for other purposes." In a deep-level shaft, the "maximum working load" consists so largely of the weight of the rope itself that when the above-mentioned rule is applied, it is found that an unnecessarily small number of persons may be carried in a conveyance of ample dimensions to accommodate more. The Commission agrees with this contention, and recommends that this Regulation be amended so as to make the limiting ratio—1 to 0.85—apply to the relation between the weight of conveyance and mineral contents to the weight of conveyance and persons.

The Best Method of Attaching the Rope to the Load.

112. The method of making this attachment, commonly called the capping of the rope, is a matter that merits close attention and has, during the last few years, been the subject of many contributions to the engineering societies and the scientific press of Great Britain. The ideal capping should be at least as strong

*Article No. 40 (i).

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as the rope; it should be easily accessible for examination of the interior and should be easy to make.

113. From the evidence brought before the Commission, there appears to be great diversity of opinion as to whether a splice, coned socket, split socket or clips is the most satisfactory attachement. All of these methods have their disadvantages. Some cappings are open to the objection that they screen off an important part of the rope from examination. With few exceptions, their efficiencies are very low as compared with the strength of the rope. Experiments have been made from time to time, both in England and other places, to determine their respective efficiencies by means of test.

The Transvaal Mines Department has also made a special series of tests of the different methods of attachments in use on the Witwatersrand mines. The results, together with sketches, are appended to this Report, from which it will be seen that these vary from 71% up to 100% efficiency. The most variable results are obtained from the conical socket, in which the wires of the rope are opened out and turned back to form a cone which more or less fits the interior of the socket, the interstices being run up with some suitable white metal.

114. In the experiments with eight conical sockets, the lowest efficiency obtained was 71.12%; while in three cases the rope itself broke quite clear of the attachment. A good deal of the variation is doubtless due to the difficulty of running in the metal in such a manner that it forms a solid cone with the wires. In some cases it is little more than so much packing, the result being that the strain comes on the wires that are bent around at the base of the socket, and this invariably makes them break at that point.

Recently, in South Wales, a Rope Caps Committee conducted a number of tests of this conical socket, and obtained efficiencies varying from 35.3% to 76.5% and averaging 56.9% for six cappings. The Committee reported that: "The direct cause of giving way in all cases was the rupture of the wires at the place where they are doubled back to form the cone, and this appears to be the weakest point in our present method of capping."

115. If it is necessary, owing to the want of head

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room, to use this class of capping which has the advantage of being very short, the best way to make it up is to leave the wires straight, and to clean and tin them before drawing down the socket over them. The next step is to pour in a white metal the melting point of which is less than 500° F., as is done in public testhouses.

116. Splices are very satisfactory, both as regards their efficiency and the ease with which they can be examined, but it requires a skilled artisan to make them in a satisfactory manner. Unless a mine is sufficiently large to find constant employment for such a man, this method of capping presents difficulties.

117. Probably the most satisfactory method of attachment, where there is sufficient distance between the pithead sheave and the point where the skip or cage is unloaded, is to use clips of an approved pattern. From experiments made, it is found that a clip of the Crosby type, which provides a good bearing surface, is to be preferred to others where the bearing area is little more than a series of points, and which, to get any grip on the rope, must damage it locally. The clips should be sufficient in number, say five in the case of a rope of 1⅛-in. diameter, and spaced 1 ft. apart. The lowest clip should be quite close to the pear-shaped thimble or eye.

118. It is obviously a very simple matter to connect a rope to the load in this way, and the exterior of the rope is easily accessible for examination. This capping has also the advantage of a high efficiency—about 90%.

119. There appears to be no doubt that safety chains are an advantage on a man-cage or skip, and are recommended; and these, as well as all other attachments, should be made either of the best mild steel or the very best brand of iron (Lowmoor, Swedish Charcoal, etc.). If made of iron, these attachments should be annealed at regular intervals.

The factor of safety should be at least as high as, and preferably higher than, that borne by the rope, on account of the shocks to which such attachments are subjected, which in time have a tendency to make the iron or steel brittle. For this reason, iron is to be pre-

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ferred to steel for this service, as the annealing of the former is far more likely to be efficiently carried out.

The Commission does not recommend the use of a swivel connection between the rope and the load, except in the case of sinking, where an unguided conveyance, such as a kibble, is used for hoisting. A swivel has the effect of untwisting the rope and making the wires slack. It may be an advantage to let out of the rope that tendency to untwist which is due to the stretching effect of the load. In such a case, disconnect the load at the bottom of the shaft once or twice, soon after a new rope has been put to work, and connect up again after the rope has stopped spinning.

120. A spring connection would probably minimize the shock on the rope where short ropes are used, but its use is not necessary in the case of a deep shaft on account of the great elasticity in the rope itself. If it is intended to fit any spring relief, the most practical method of doing this is to have the springs arranged in a frame under the plummer blocks that carry the pit-head sheaves. The blocks must be allowed to move only in synchronism, and not independently, as the latter would tilt the axle and sheave.

The Reliability and Adaptability of Safety Catches and Appliances in Shafts.

SPEED CONTROL.

121. For controlling the speed of winding and for generally securing smooth running, the use of a properly adjusted governor and a recording tachometer is recommended. The control of the steam throttle-valve should not be taken out of the engine-driver's hands by any automatic device, unless such device be fitted so as only to come into action to prevent an overwind. The governor should operate on the cut-off mechanism, and thus prevent over-speeding at any period of the winding.

122. The recording tachometer will give a permanent record of all trips made and the speed at which the winding was done. While it exerts only a moral influence to prevent accidents, still, should an accident occur, it will prove a great service in supplying a reliable

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impersonal record of the speed of winding at the time, and the behavior of the engine.

OVERWINDING PREVENTION DEVICES; SAFETY HOOKS.

123. With respect to the prevention of the overwinding of the conveyance, the necessity for some device to effect this prevention will be apparent when one considers the number of accidents that occur, and also the loss of life and damage done to the winding plant, due to this cause.

ACCIDENTS DUE TO OVERWINDS.

124. The following are the statistics of "overwinds" that occurred during the 2½ years ended December 31, 1906:

Total number of accidents 67, of which 9 were fatal.

Cases in which overwinding hooks were fitted..... (8 successful; 2 not brought into action owing to jamming of conveyance in headgear).	5
Cases in which "visors" were fitted..... (Unsuccessful; driver had reversing lever the wrong way).	1
Cases in which no overwinding hooks or "visors" were fitted	61
Total	67
Cases in which an overwinding hook would have prevented the cage from going to the bottom of the shaft after rope fracture, and probably saved life	5
Cases in which an overwinding hook would have prevented the cage from going to the bottom of the shaft after rope fracture, and probably prevented damage to property	40
*Cases in which overwinding hooks could not have been fitted, or would have been useless	22
Total	67
†Cases in which the engine-driver overwound, due to his own neglect	56
Cases in which the engine-driver overwound, due to other causes	11
Total	67

*These cases consist of such accidents as when the engine-driver overwound on the down trip, overwinding on inclined shafts, skips jamming in the tips, etc.

†These accidents were caused by the main steam valves breaking, indicators slipping, wrong signals, other persons interfering with engine, brakes not acting, shoe in reversing link stuck, engine running out of control.

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Cases in which overwinds caused fatal accidents at the bottom of the shaft 8
Cases in which the engine-driver had his reversing lever in the wrong direction, and thus caused an overwind 13

125. Since the beginning of the present year, 1907, there have been three cases of overwinding in which the detaching hook acted successfully. The suspending of the cage after the ropo was freed was effected by safety catches, the wings of the hook not being required for this purpose. In two of these cases, persons were traveling and were saved from serious injury. Three safety hooks were officially tested and were quite successful in their action.

126. The Commission reports unhesitatingly in favor of detaching hooks for winding in vertical shafts, with the limitation that, where rests are used for loading in very deep shafts, the heavy hook is a possible source of danger—the length and weight of rope hanging in the shaft making it difficult for the engine-driver to control the amount of slack given out, thus leading to the chance of the hook bumping on the top of the cage.

The detaching hook is not recommended for use in inclined or compound shafts where pulleys are used for the rope to run over; as there may be a danger of the hook, of whatever design, striking such pulley and coming into premature action.

127. The extent to which safety hooks and overwinding-prevention devices are used in the Transvaal is set forth below, together with the opinions of the mine managers regarding their efficiency.

AUTOMATIC DEVICES TO PREVENT OVERWINDING.

128. The following table summarizes the information furnished to the Commission in regard to the use in the Transvaal of automatic devices to prevent overwinding:

	Gold mines.	Coal mines.
With safety devices.....	7	2
Without safety devices.....	117	19
Tested with satisfactory results..	6	1
Tested with unsatisfactory results	0	0
Operated successfully	2	1
Operated unsuccessfully	0	0

129. The 7 gold mines have 9 automatic devices to prevent overwinding, and, of these, 6 are reported as being

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perfectly satisfactory; the remaining 8 are unsatisfactory, and the reasons given therefor are that they detract from the proper working of the depth indicator, and if called into action the sudden shock is likely to damage the winding plant seriously.

130. Eight of the above devices act on the steam supply to the winding engines, as well as on the brakes, the remaining one acts on the brakes only.

131. The methods in which these devices operate are as follows:

Four speed safety devices are operated from a Bertram visor gear acting in conjunction with the depth indicator; one is operated through the depth indicator and also by hand from the engine-driver's platform; one is brought into action by the drag-link on the crank-pin, and also by a knocker-device in the headgear in case the engine-driver starts the engine in the wrong direction; and three are operated through the depth indicator only.

132. In the case where the overwinding device is operated by means of the depth indicator, if the latter goes wrong an overwind is not likely to be prevented. This has been the cause of some accidents locally, so that it is considered that the overwinding-prevention device should act quite independently of the depth indicator.

ROPE-DETACHING HOOKS.

133. The following table shows the number of gold and coal mines in the Transvaal where safety hooks are in use:

	Gold mines.	Coal mines.
With safety hooks	13	13
Without safety hooks	111	10
Tested with satisfactory results..	7	10
Tested with unsatisfactory results	0	0
Operated successfully	6	8
Operated unsuccessfully	0	0

134. On three gold mines where no safety hooks or overwinding-prevention devices are in use, two have loops provided in the headgear into which the wheels of the skips will run and so prevent the skip falling in the event of the rope breaking owing to an overwind. The third has converging guides so that the skip will be held fast in these in the event of an overwind.

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135. The Commission has not had the opportunity to test any of the speed safeties or other overwinding-prevention devices, and is not in favor of making their use compulsory.

This corresponds with the recommendation of the Dortmund Commission in 1903, in which mining district there are many speed safeties of various patterns at work, none of which were considered sufficiently reliable to recommend definitely.

136. Converging guides, buffer beams, safety keps or catch beams are not made use of to any great extent in the headgears of the Transvaal mines; but their use is recommended, not compulsorily, in those comparatively few cases where the tipping arrangements of the skips will allow of their being fitted.

137. The present Regulation* which provides for a reduction in speed on nearing the surface, in cases where no automatic overwinding-prevention devices are installed, is doubtless of some service in preventing accidents; but there appears to be something more necessary.

138. In 2½ years, out of a total number of 67 overwinds, 56 were due to the engine-driver's neglect; and of this number 13 were caused through the engine-driver having his reversing lever in the wrong direction. The majority of these drivers were certificated and there no question arose as to their competency. From the annual reports of the Government Mining Engineer, it will be seen that the Inspectors of Mines have not hesitated to apply Article 154, which provides for the suspension of certificate in case of gross inattention or negligence; and it can only be hoped that a continuance of this practice will in time bring about the desired result.

A contrivance attached to the reversing gear, to prevent the engine being started in the wrong direction, would be of service; but the Commission is not in a position to recommend the compulsory use of such a device, as its reliability must first be thoroughly established by practical trials.

*Article 40 (g)—see page 84.

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ACCIDENTS DUE TO RUNAWAYS.

139. In the period above referred to, the following accidents were due to "runaways" of skip or cage:

Total number of accidents 31, of which 8 were fatal.	
Accidents due to neglect of engine-driver	15
Accidents due to other causes	16
Total	31
Accidents due to clutch breaking or coming out of gear	5
Accidents due to other causes	26
Total	31

140. These accidents were due to clutches breaking or coming out of gear, brakes failing to act, pinion of spur-gearing breaking, or unauthorized persons tampering with engine.

141. Two accidents, in addition to those stated above, were caused by the rope slipping on sheaves of Whiting hoists.

142. Of the 15 accidents due to the neglect of the engine-driver, the most general cause was the unclutching of a drum which was either not braked or insufficiently so.

Fracture of Winding Ropes, Safety Catches, Etc.

143. In the statistics published hereunder, it will be seen that the only instances of the successful operation of safety catches occurred at the time of overwind on the up-trip. These may be supplemented by the three similar but later cases mentioned in paragraph 124:

ACCIDENTS IN WHICH THE ROPE OR CONNECTION BROKE.

Total number of accidents 51, of which 18 were fatal.	
Accidents due to faulty ropes	8
Accidents due to faulty connections	10
*Accidents due to other causes which broke rope or connection	33
Total	51

*These accidents were due to overwind, skips being derailed, engine driver losing control of engine or drum, rope jumping pit-head sheaves, truck coming loose in cage, skips jamming in shafts, etc.

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Of these 51 accidents, the cage or skip was fitted with safety catches in 9 cases, 2 of which were successful and 7 unsuccessful.

Cases in which an efficient safety catch would have saved life	13
Cases in which an efficient safety catch would have saved property	28
*Cases in which an efficient safety catch would have been useless	10
Total	51

144. The two instances in which the safety catches acted successfully were on the up-trip; the engine-driver overwound the skip and broke the rope, as no detaching hooks were fitted.

145. Of the 7 instances of unsuccessful operations quoted above, 2 were on the up-trip and 5 were on the down-trip. Three were cases in which the cage reached the bottom of the shaft before the rope broke. In 1 case the supplementary safety chains supported the load; so that in this and the 3 preceding cases, the catches did not have a chance of coming into operation, the king-bolt spring remaining compressed. In 2 cases the cams of the safety catch were not properly designed, the angle of the wedging action being too great.

146. In paragraphs 19 to 25 of this report, the historical side of the safety-catch question has been dealt with; and from a study of this section, the references quoted, and statistics of shaft accidents generally, there can be no doubt in the mind of any person as to the necessity of using a reliable safety catch, if such an appliance exists. However much stress is laid on the necessity for securing the best possible winding rope, and for its being carefully and intelligently examined during its working life, it must be evident to all that a good sound winding rope is not, by itself, a sufficient safeguard.

147. Statistics conclusively show that safety catches of themselves are not necessarily an additional source of

*These cases include skips coming off the track on the incline and those in which the drum had become disconnected from the engine, the engine-driver losing control and the skip going to the bottom of the shaft before the rope broke.

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danger to persons traveling in mine shafts, while on the other hand they have saved life on many occasions.

148. From the commencement of its work, the Commission has taken up this attitude, and has worked on with the idea of establishing the reliability of selected devices.

149. The Regulation* dealing with the use of safety catches states that, except during sinking operations, they shall be provided where applicable; and it has been customary for this reason, in the Transvaal, to exempt cages, skips, and other conveyances working in inclined or compound shafts, or in vertical shafts fitted with steel guides. Reserving for future consideration the cases of inclined and compound shafts, the Commission noticed at once that the safety catches used in vertical shafts were not in any way reliable; and while the use of steel guides was generally increasing as deeper levels were opened out, no suitable safety catch was put forward to meet this growing need.

150. Seeing that wire-rope conductors were but little used in the Transvaal, and that their very limited use was not likely to extend, the inquiry was also justifiably limited to meet this circumstance.

151. Of the 84 designs submitted, the Commission selected 5 for trial, 2 of which were presumably equally applicable for conveyances traveling on wood or steel guides. In the latter category were placed the Wilkinson and Schweder devices, while the Undeutsch, Hughes and Garvin appliances were, in the submitted designs, only suitable for timber guides. Jensen's safety catch, for use with steel guides, was favorably noticed, but the working drawings came to hand too late for the device to be tested practically. Thomson's safety catch, which was not selected by the Commission, was, however supplied in working shape by the inventor, and the trials were witnessed and reported on.

152. [An abstract of the details of these tests, digesting briefly and broadly the data given in the "annexures" to the report, and including drawings of the most important of the catches, is given on pages 58 to 78.]

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*Article 40 (k)—see page 86.

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153. In justification of the Commission's selection, and in explanation of the failure of more than one of the appliances, the following remarks with respect to the necessities of a good safety catch are put forward:

154. The selected designs did not, in every case, possess all these qualities, but it was considered desirable to test them, either to prove that they did not do so, or to establish, practically, the necessity for these attributes.

(1) The instantaneous release of tension in the rope, at the time of its fracture, must immediately be taken advantage of through the medium of some spring connection (not necessarily metallic) to operate, by one means or another, the retarding agency. The releasing of a weight without any spring impulse is not likely to be effective, as it is difficult to attempt to disturb in this way the natural zero relative motion of all the moving masses.

(2) The movement of the spring can be best utilized to create a small relative motion of the draw-bar (kingbolt) of the cage.

(3) The motion of the draw-bar should be utilized to work the brake mechanism in a manner so far non-reversible that, once the brake is in action, it will require an actual raising of the cage, or a rope-pull equivalent to it, to release it in the slightest degree.

(4) The tension in the spring should be as small as possible—certainly not more than half the weight of the empty cage—so that the catches shall not be brought into action, when not required, by the pulsations of the winding rope.

(5) Seeing the instantaneous nature of the operation, and the small force disposable to effect it, the weight of the actual moving parts should be reduced to a minimum.

(6) The force necessary to produce any retardation in a pulling body must be at least equal to the weight of the body itself. If this force is only equal to the weight of the body, then no retardation occurs, the force of gravity is exactly neutralized, and the body continues in uniform motion downwards with the velocity it possessed at the instant of the application of the force. It is therefore necessary to supply something more than this, if the body is to be stopped.

The difference between the catching force (supplied by the safety catch) and the weight of the loaded cage is the amount available for retardation. On the amount of this difference, and on the suddenness of its creation, depends the shock to the occupants of the cage and also the braking distance, this latter being also influenced by the velocity of the cage, the relation being directly as the square of this velocity.

The retarding action of a good safety catch should therefore conform with these principles, and ensure the

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arrest of the cage, even on the downward journey, without injury to the occupants.

(7) The retarding force, whether produced by deformation and friction with wooden guides, or by friction on steel guides, should be, within practical limits, independent of the amount of reduction in size due to wear that the guides have previously sustained.

(8) The direction of application of the retarding force should be such that the guides and their supplementary framework are maintained in position.

(9) The safety catch, having stopped the cage, should maintain it in position until it is again lifted.

(10) The safety catch should be equally reliable in its action whether the rope breaks on the ascending or descending trip.

(11) The mechanism should be capable of ready examination, and designed with due consideration to the severe working conditions that it has to meet with in mining practice.

155. With reference to condition (6) mentioned above, the question of what is a safe braking distance is not yet answered. A man, if prepared, can fall several feet without injury, but a small distance taken inadvertently may produce injury. For use in the tests at the Marcus shaft, a shock-meter was prepared and calibrated on the free fall system to indicate the extent of sudden arrest. With a 2-ton cage falling at the rate of about 1,200 ft. per min. and stopped in 2 experiments in 13 ft. and 15 ft. 5 ins. respectively, the indicator showed 4.4 ins. and 3.25 ins. Practically the same result was obtained, considering slightly altered adjustment of the safety catch to suit worn guides, with a greater velocity and a longer travel.

156. These measurements of the indicator represent the suddenness with which the full braking action of the safety catch is developed, bearing in mind that the braking action is equal to the excess of the maximum catching force over the weight of the loaded cage.

157. These values, varying from 3.25 ins. to 4.4 ins. with the Garvin and Undeutsch safety catches when the total load was 2 tons, show that these devices, if properly adjusted, are not likely to cause serious injury to persons; and that they will bring the falling cage to a standstill in a reasonable distance, say from twelve to thirty feet, this amount of travel depending on the downward velocity of the cage at the time of rope fracture. Both these safety catches are adjustable so far as

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the shock is concerned, provided that the guides do not vary appreciably in width at different places in the shaft. In the case of the Undeutsch catch, from the shape and arrangement of the knives it is not probable that a variation of a half-inch in the width of the guides, involving a quarter-inch variation in the penetration of the knives, will cause much alteration in the shock.

158. The Garvin safety catch fails in this respect, and, until automatic adjustment of the penetration of the wedge faces is provided for, it cannot be regarded as a satisfactory device. This automatic adjustment can be provided for in a fairly simple manner, but not in so complete a way as to prevent increase of shock if the falling cage suddenly meets a guide which is wider than the one just passed over.

159. In the Schweder catch, the brake shoes having an elastic gas backing, there is produced a catching pressure which is practically independent of the width of the guides. Although the registered shocks were the same, and the loaded cage was considerably lighter in the Schweder experiments than when the Undeutsch catch was tested, there was a considerable difference in the braking distance. To reduce the braking distance in the case of the Schweder catch will probably involve an increase in the shock, but this can be kept within a safe margin by adopting in the design of the safety catch such dimensions and narrow pipe connections and ports as are suitable for the particular circumstances of a specific case. With reference to condition (9),* the Schweder device, as tried at the Marcus shaft, did not exactly comply with this desideratum, in that the slight leakage of gas from the cylinders after the catch had come into operation was found to lead to a reduction of the gas pressure, and consequently to the loosening of the grips and freeing of the cage—this happening after a lapse of time of, perhaps, half an hour's duration. The inventor, however, has now designed a supplementary arrangement which, operating by means of a spring acting against gas pressure, causes a small roller to be brought into action after the gas pressure has fallen below a certain limit and thus effectually holds the cage until it is lifted away again.

*Paragraph 154.

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160. With regard to condition (10),* no special trials were made of the selected devices on the up-trip. Incidentally, during the trials of detaching hooks it was several times proved that a mechanically operated safety catch, if properly designed and maintained in proper working order, can always be counted upon to meet this condition, viz., that of the rope breaking while the cage is being raised. The Schweder device was also considered to be perfectly reliable in this respect, and with respect to any possible danger arising from its untimely action which might be brought about by the pulsation of the rope while the load is being wound upwards, it has only to be remembered that the exhaust from the brake cylinders is quite as rapid as the inlet of gas; in fact it is practically instantaneous, so that there is no possibility of the rope being overstrained on account of the brakes maintaining any grip after the king-bolt spring has been compressed. The valve will open to exhaust just after compression of this spring starts, and the gas pressure in the brake cylinders will be relieved before the act of compression is completed.

161. The ordinary White & Grant eccentric safety catch was tested in order to demonstrate finally its unreliability.

162. Several devices were rejected because they were obviously too sudden in their action, and would give too much shock if called into action on the down trip.

163. A number of ingenious devices were not recommended for trial because they were of the "delay-action" type, and did not immediately neutralize the force of gravity. They were not sudden enough in their action, their inventors clearly not fully appreciating the laws governing the motion of falling bodies.

164. Other designs of safety catches proposed to minimize shock by means of pneumatic, hydraulic, or spring buffers built into the frame of the cage. It was considered that this principle, which had already been tested successfully in Germany, was not to be recommended owing to the great increase in weight which such a safety catch would entail if a suitable braking distance were provided.

*Article 40 (k)—see page 86.

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165. The trials of the Hughes, Thomson and Wilkinson devices proved unsuccessful. The tests of the last-mentioned safety catch in large model form gave promise of its suitability for use on steel rails, but defects in the design of the model of working size entirely disposed of all chance of success. To remedy these defects would have been very expensive, and the trials disclosed the probability of the fickleness of the device unless especially adjusted to suit any small alteration of working conditions. Owing to the complete success of the Schweder catch when used on the steel rails, further trials of the Wilkinson catch were abandoned.

166. Seeing that the possibilities of a satisfactory safety catch for vertical shafts have been established, the Commission recommends that the present Regulation† shall remain in force, and that the question of the applicability of any particular safety catch should be left to the Government Mining Engineer to decide.

167. In the same manner that the British Board of Trade permits the use of certain safety valves for marine boilers, and just as the British Home Office has published a list of permitted explosives for use in coal mines, so, it is considered, should the Mines Department prescribe which safety catches are to be classed as suitable for the various kinds of shaft.

168. The Commission, while not wholly satisfied that any of the safety catches tried entirely meet the requirements of such an appliance, considers that, of the designs submitted, the following give the best results:

For vertical shafts with wooden guides, the Undeutsch; for vertical shafts with wooden guides, the Schweder; for vertical shafts with steel guides, the Schweder; and for inclined shafts with steel rails, none at present; the Commission advises early trials of suitable designs.

169. The special conditions obtaining in each compound shaft should be investigated by the Mines Department, and a decision arrived at in each case regarding the applicability of safety catches.

170. The Commission recommends that no safety catch should be placed on a "permitted" list until its reliability has been thoroughly established by tests similar to those carried out at the Marcus shaft—such tests to be conducted at Government expense and under the direc-

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tion of the Government Mining Engineer, with previous advertisement in the daily press. It is also considered that the inventor should supply and deliver at the testing station, free of cost to the Government, the full-sized working appliances ready to be fitted to a cage of standard dimensions.

GENERAL SAFETY MEASURES.

171. Some other points likely to affect the safety of persons were touched upon by Mr. Robert Briggs, one of the oldest engine-drivers on these fields. He represented the South African Engine-Drivers' and Firemen's Association, and in this capacity spoke in favor of extending the list of authorized signals, of isolating the winding engine from all other machinery, and of bringing into general use a bell signal recorder. He also spoke in condemnation of barrel indicators as causing constant strain on engine-drivers' eyes, and was averse to the use of the chain drive for operating the depth indicator.

172. The Commission considers that it is inexpedient to increase further the list of authorized signals to the extent suggested. Owing to the various kinds of mines and the different kinds of shafts, complete standardization in the matter of signalling is impossible. There appears, however, no objection to, and considerable reason for, universal signals in the cases of transport of explosives, notifying accident or emergency, and request for repetition of signals.

173. The isolation of the winding engine is a very necessary thing so as to keep the driver as free as possible from distracting influences, but there are practical difficulties in some cases which prevent this custom being universally adopted. The Commission is, therefore, unable to recommend that this practice shall be established absolutely by the regulations. The Inspector of Mines, at the present time, has the power to insist on isolation where necessary, and the Commission considers that this provision is satisfactory.

174. With regard to the use of a bell signal recorder, the Commission considers this very desirable, but, from the very limited experience with any such apparatus, it is considered premature to make this a compulsory attachment to each winding engine.

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175. Concerning depth indicators, there can be no question that the dial and the pillar types are in most general use, and that they afford to the driver the clearest and most precise indication of the position of the vehicle in the shaft. A very necessary stipulation should be made, however, viz., that the travel of the pointer between the "tip" and the extreme bottom of the shaft should not make a complete revolution, within three inches, on the circumference of the dial. The barrel type of indicator should always be so arranged that the pointer, while giving a fine reading in conjunction with the spiral grooves, also provides a rough indication in its own vertical guide. Regarding Mr. Briggs' objection to the chain-driven indicator as being unreliable, the same objection also applies to bad examples of other forms of drive. A good chain and sprocket gear is universally recognized as being a sound mechanical device, although requiring, perhaps, more attention in the way of adjustment that toothed gearing; and there is, therefore, no reason for prohibiting its use.

SINKING WITH BUCKETS OR SKIPS.

176. A considerable amount of evidence was taken as to the relative advantages of the use of buckets or skips in the sinking of deep shafts, the Commission being anxious to obtain the best opinions as to the safest methods of deep-level sinking—a subject which has caused a large amount of discussion during the past three years.

177. From the evidence before the Commission, it is not possible at present to advise upon any hard and fast regulations dealing with this matter; the question of whether buckets or skips are least dangerous depending largely upon the personal element in actual working and supervision and upon details of ropes and winding plant.

178. Until recently, sinking with buckets has been the method most employed, and the number of recorded accidents show that a considerable amount of danger attends this method of sinking. The use of buckets has been rendered safer by the use of the Berry crosshead (See Fig. 7), and the Commission is of the opinion that an approved crosshead is essential in this method of sinking.

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179. The Mining Regulations prohibit persons riding on the top or rim of a loaded bucket, and the Commission considers that this regulation should apply to empty buckets as well, in order to avoid an unevenly balanced load swinging in the shaft, and also to prevent any accidents due to the clothes or bodies of persons riding on the bucket rim catching on the shaft timbers. In addition to this extension of the regulations, the Commission considers it necessary that a loaded bucket should, when being raised to the surface, stop when the crosshead is picked up; and that it should be rung away by signal from this point of stopping, so as to ensure a steady lift to the surface when the engine-driver puts on speed.

180. The use of sinking skips is, from a safety point of view, superior to that of buckets; but, while not giving so many opportunities for hoisting accidents, it can also be a source of considerable danger. The long runners on a sinking skip are a great disadvantage, there being a difficulty in giving a sufficient clearance between the long runner and the guide; and, on occasions, serious shaft accidents have been caused by the skip sticking in the shaft when being lowered or raised on the long sinking runners.

181. In face of the recorded number of accidents with sinking buckets, as shown in the Mines Department annual returns, deep sinking with skips is to be recommended as the safest method, inasmuch as a guided skip, not having the freedom of the sinking bucket, is effectively fixed in the shaft; is unable to swing, spin or strike the walls of the sinking compartment; and is not so much dependent upon careful hoisting, or the initial steadying of the load to be raised, as in the case of a sinking bucket in shafts that are not close timbered.

182. In placing our report in the hands of Your Excellency, we desire to express our recognition of the responsible work which has devolved upon the Secretary, Mr. J. R. Mackinlay, who has rendered us material assistance by the energetic and zealous manner in which he has performed his duties. Our thanks are also due to Mr. W. Martin Epton, Government Inspector of Ma-

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chinery, and to Mr. J. A. Yule, Engineer of the Langlaagte Estate and Gold Mining Co., Ltd., for the very valuable services rendered by them in carrying out the practical tests at the Marcus shaft, and for the information supplied by them for this report.

[We give below in full the names of the signers of the report, with their official connections.—Ed. Eng. News.]

U. P. SWINBURNE, Acting Government Mining Engineer (Transvaal), Chairman.

WAGER BRADFORD, Manager, Langlaagte Deep Gold Mining Co., Ltd.

H. C. BEHR, Consulting Mechanical Engineer, Consolidated Gold Fields of South Africa, Ltd.

J. F. COOK, Consulting Mechanical Engineer, S. Neumann & Co.

E. FARRAR, Consulting Mechanical Engineer, General Mining and Finance Corporation, Ltd.

J. S. FISHER, Inspector of Mines, Johannesburg.

GEORGE C. FOX, Consulting Mechanical Engineer, A. Goerz & Co., Ltd.

DAVID GILMOUR, Consulting Mechanical Engineer, Johannesburg Consolidated Investment Co., Ltd.

J. A. HEBBARD, Manager, Langlaagte Estate and Gold Mining Co., Ltd.

FRED HELLMANN, Consulting Engineer, East Rand Proprietary Mines, Ltd.

W. L. HONNOLD, Consulting Engineer, Consolidated Mines Selection Co., Ltd.

EDWD. HOPPER, Consulting Engineer, Representing the Transvaal Chamber of Mines.

J. HARRY JOHNS, Consulting Engineer, Johannesburg Consolidated Investment Co., Ltd.

C. J. PRICE, General Manager, Central Administration.

A. M. ROBESON, Consulting Mechanical Engineer, H. Eckstein & Co.

H. ROSS SKINNER, Manager, Durban Roodepoort Gold Mining Co., Ltd.

J. W. H. STUBBS, General Manager, Randfontein Estates & Gold Mining Co., Ltd. (Witwatersrand.)

S. C. THOMSON, Consulting Engineer, S. Neumann & Co.

J. A. VAUGHAN, Chief Inspector of Machinery (Transvaal).

EDWARD J. WAY, General Manager Kleinfontein Group of Mines.

Johannesburg, May 7, 1907.

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Tests of Safety Catches.

We have published the complete report of the Commission in our issues of Oct. 31 to Nov. 21. In the volume in which it was originally published, the report proper occupied 34 pages of a pamphlet 8 × 13 ins.; while the supplementary information—descriptions of apparatus, details of tests, cuts, etc.—were arranged after the report proper in a "schedule of annexures" covering 75 pages.

The arrangement of the data and results of the various experiments, in this "schedule of annexures," is chronological instead of according to devices, and hard to follow; the matter is also very voluminous. We have therefore made the following abstract of the tests on the principal devices, considerably condensing the details.

THE MARCUS SHAFT.

Preliminary to a description of the tests of safety catches covered by paragraphs 143 to 170, inclusive, of the report, some idea should be given of the Marcus shaft of the Langlaagte Estate and Gold Mining Co., where the tests were conducted, and of its equipment.

It is a 3-compartment shaft, with one compartment for pumps and ladders and two for hoisting. The depth is 597 ft., and the shaft is timbered with 8 × 8-in. pitch-pine sets. Fig. 1 shows a plan of the collar set, with the 4 × 4-in. pitch-pine guides.

The headgear, or gallows frame as it is called in this country, is of steel, 33 ft. high and fitted with 8-ft. sheaves. The height from the collar of the shaft to the overwinding attaching plate is 27 ft. 5 ins.

The hoisting engine is of the double-cylinder geared drum type, with 18-in. cylinders and 28-

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in. stroke, working at a steam pressure of 90 lbs. The drums are 8 ft. in diameter, and the gear reduction is 1:8.7. During the tests a tachometer was fitted to the drum shaft, to indicate the speed of hoisting.

Fig. 2 shows one of the cages used in the experiments. They are designed to carry a car containing 1 ton of material, and are fitted with the ordinary eccentric toothed-cam, spring-actuated safety catches of the White & Grant type*—somewhat similar to those used in this country—which the springs cause to bite the guides upon

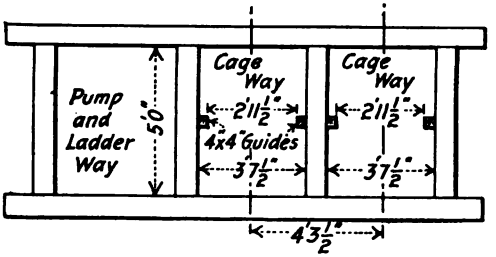

Fig. 1. Plan of Collar Set, Marcus Shaft, Langlaagte Estates & Gold-Mining Co., Transvaal.

the detachment of the rope and which the weight of the cage tends to force into still closer engagement. The "heels" or stops, on the shafts carrying these cams (see plan and side elevation, Fig. 1) were added after the first experiment. The teeth of these cams on the Marcus shaft cages, it should be mentioned, had been "completely worn away by use, on the greater part of the cam." The detaching hook used was of the King-Humble pattern.

*See paragraph 161 of report.

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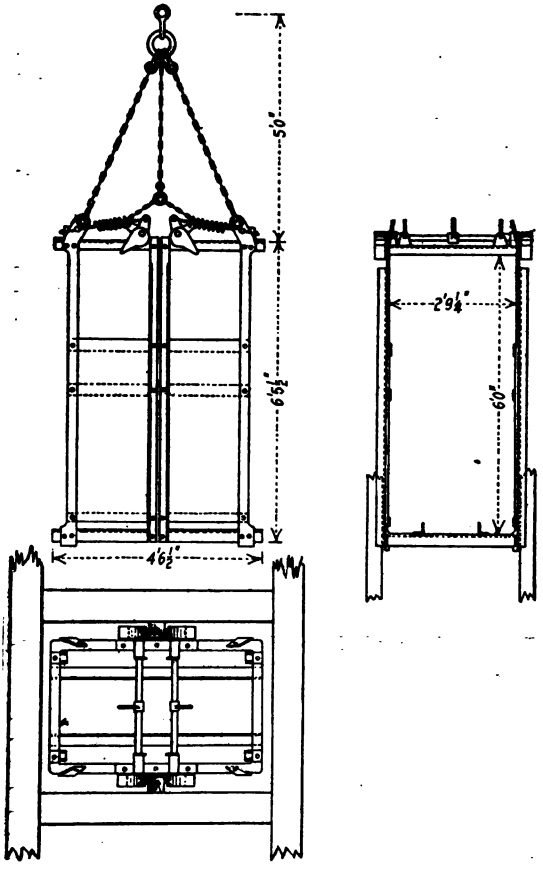

Fig. 2. Type of Cage Employed at the Marcus Shaft, Transvaal, as Originally Used.

(The heels or stops on the cam shafts were added after the first experiments. The catches shown here are of the White & Grant type.)

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DETAILS OF TESTS.

FIRST TEST.—This test was made simply to try out the ordinary safety devices already on the Marcus shaft cages. In the first experiments, with the cage empty (the ordinary cage, with no especial preparation of any kind) it was intentionally overwound—hoisted slowly from the surface to the sheave. The detaching hook worked satisfactorily, freeing the rope and leaving the cage apparently hanging from the plate by the detaching hook; on closer inspection, however, it was seen that the chains were slack and that the safety catches were holding the cage—three cams having taken hold. This is worthy of note, because the King-Humble hook allows the cage to drop about 2½ ins. after detaching the rope before the wings, which project to hold the cage, come into action; the promptness of the operation of the White & Grant safety catches is shown up very clearly

In the second set of experiments, various conditions were imposed with the cage both empty and loaded. It should be said here that the empty cage weighed 1,700 lbs'; and that the rope, a round one, was 1⅛ in. in diameter; also that the aggregate strength of the springs operating the safety-catch cams was 815 lbs.

A spring balance was suspended in the cage, to determine the amount of shock at the stoppage of the cage. In one trial, with 67 lbs. hung from the spring balance and the cage released from rest, the balance registered a shock of 300 lbs. The cams gripped immediately and did no damage to the guides. In another trial, with 150 lbs. on the balance and the empty cage dropped with 3 ft. of initial downward start, the balance broke loose and the guides were badly amaged by the cams when they took hold.

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In a similar trial where the cage, loaded with about 3,000 lbs., was dropped with 3 ft. of initial start, the cams cut enough timber out of the guides to allow them to turn completely around; and at the same time the cam shaft was bent. The cage, after a momentary check (during which time the damage was done) fell freely until caught by the stops at the shaft collar—these trials being made above ground, in the frame.

Means were provided, to give the 3-ft. start before the cams should operate, for holding the cams from operating by means of a chain and clip, released after a 3-ft. drop.

The "heels" shown on the cams, in Fig. 2, were attached after these trials to ascertain their value in preventing the complete turning of the cams, the same cage being used. While the guides were cut into by the cams, from ½-in. to 1 in., the catches acted satisfactorily in the above-ground trials.

In a further trial, the cage descending in the shaft at about 1,700 ft. per min. when released, and carrying a 3,000-lb. load, the cage fell over 40 ft. before it was caught; and it was thrown to a horizontal position across the shaft, the catches seeming to have acted violently and breaking the guide completely on one side.

The resultant of all of these trials of the White & Grant catch was, as is stated in paragraph 161 of the report, to prove the catch unreliable.

TESTS OF THE HUGHES SAFETY CATCH.* —Briefly, this consists of shafts fixed across the top of the cage, to which are attached two eccentrics. Connected to the eccentrics are two levers with retarding shoes attached. When the rope breaks the eccentric shafts act, and upon the cams coming into contact with the guides

*See paragraph 165 of report.

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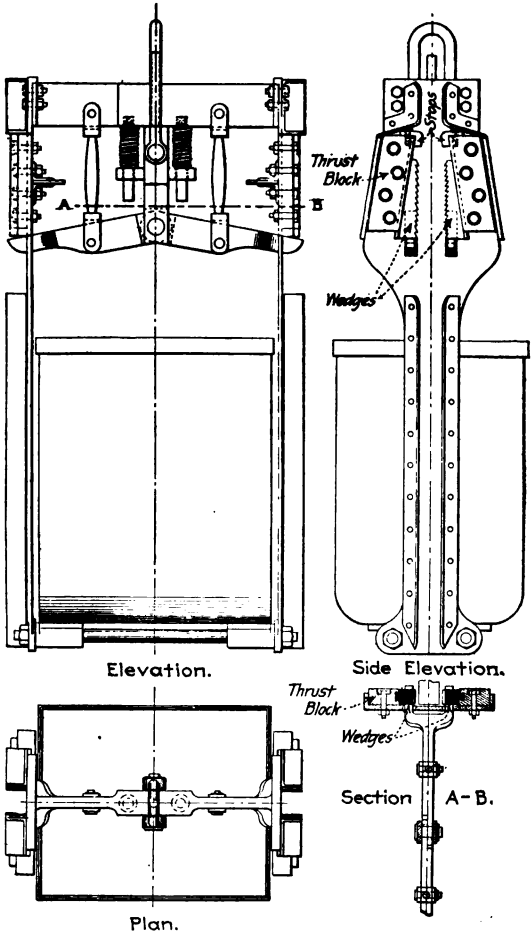

Fig. 3. Diagram of the Garvin Safety Catch.

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"an infinite stress is set up between the guides and the retarding shoes."

Four preliminary trials were made of this device, and five subsequent trials. As stated in the report, it proved unsatisfactory.

TESTS OF THE GARVIN SAFETY CATCH.—This device is shown in the drawing reproduced in Fig. 3. It consists of wedges at each side of the guides, having ⅝-in. teeth ½-in. apart on their acting faces. These wedges are forced into action, when the rope breaks, by being pushed upward by the forked ends of a pair of toggle levers, operated by the springs shown in the drawing. The device of itself weighs 1,690 lbs. As shown in the drawing, it is attached to a bucket instead of a cage.

A considerable number of tests were made of this device; first in the form shown, and subsequently with various alterations. The stops shown directly above the wedges were added after the first trial, and were lengthened by 1 in. after the second; a still further reduction of ¼-in. in the travel of the wedges was made later. After the first trial the number and width of the teeth were twice reduced, with considerable reduction in the wear and tear on the guides.

With loads varying from 800 lbs. to 2,800 lbs. (making, with the 1,500 lbs. of the cage and 1,690 lbs. of the device itself, totals of about 4,000 lbs. to 6,000 lbs.) and various conditions of dropping—similar to those imposed in the tests of the ordinary devices on the cage—tests were conducted on a number of occasions during a period of a year, and with the different alterations which we have already noted.

Without going at length into the details of these tests we may say that the principal objections which characterized the Garvin device

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were its suddenness of stopping action, with attendant shock to the cage and its load (a serious consideration where the load may be men) and its effect in damaging the guides. In tests where the cage would be caught and held positively—in some cases with a preliminary downward run at high speed—the wedges would always be driven home to the stops, and the teeth well into the guides.

In one case a downward run of 414 ft. per min. was given, and the rope—552 ft. long—disconnected with the cage falling at 2,500 ft. per min. as registered at the tachometer of the engine. Although the teeth on the wedges penetrated the guides ⅛-in. in all the way down, after disconnectiog, the cage and its load, totaling 4,000 lbs., were not held and fell clear to the penthouse which had been erected in the shaft.

On the whole, then, the Garvin device did not prove satisfactory under the tests. The fact that the Commission continued the tests for a year, however, is worthy of note.

TESTS OF THE THOMSON SAFETY CATCH.—This device consists of two pairs of flat brake shoes, 10 × 2½ ins., which, when brought into action by means of a vertical lever arm hinged to back of each shoe, exert a gradually increasing pressure on the sides of the guides. In each lever is a long slot in which works a roller, ¾-in. in diameter, forming the axle of a pair of large rollers 6 ins. in diameter which bear against the side of a guide when the catch is brought into action. The large roller then revolves, and in doing so travels upwards along the slot in the lever—the slot being set at an angle with the shaft guide, so that as the roller travels along it the lever arm is forced out-

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wards and presses the brake shoes into engagement. The device weighs 420 lbs.

Tests were made on this catch on two occasions. After the first trial, a rack was cut in one face of each of the slots and pinions running therein substituted for the small rollers, to ensure the travel of the large rollers up the slot when set in rotation by contact with the shaft guides.

Briefly, the device failed to hold the loaded cage (4,000 lbs. total) in any trial, the rope loosened from a position of rest. In none of the trials, even after the racks and pinions were fitted to ensure the travel of the shafts of the rollers up to the inclined slots, did the brake shoes exert sufficient pressure on the shaft guides to produce satisfactory operation.

TESTS OF THE UNDEUTSCH* SAFETY CATCH.—A drawing of Prof. Undeutsch's device is shown in Fig. 4. To quote from a letter of his written to the Commission on Jan. 6, 1906:

> The author has based his safety catch on the principles of the simple brake used with children's sledges, and on the position of a man climbing up or down two poles. The main principles which underlie the design of his brake are simple and narrow arms or catches, which should be indestructible, whose penetration into wooden guides should be limited and which should have knife or chisel edges.
>
> The shock to persons is reduced to a minimum, and is then not dangerous. It is independent of the height of free fall, i. e., of the square of the final velocity, whatever the speed of descent of the cage after the rope breaks might be.
>
> The relation of these retarding knife edges to the guides is shown in the plan and side elevation in the drawing. The edges are parallel to the length of the shaft guides, and there are

*Prof. H. Undeutsch, Freiberg, Saxony.

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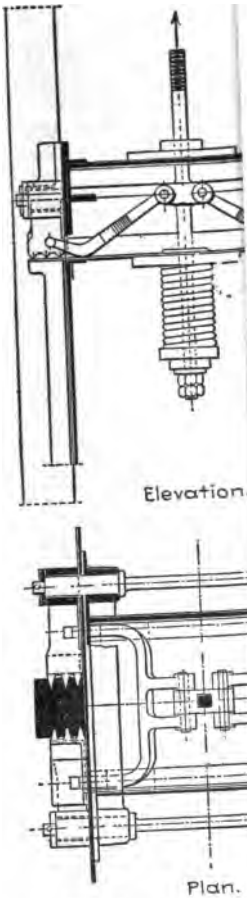

FIG. 4. DIAGRAM

(The solid-black porti
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12 in all—3 on each side of each guide. These edges are 1 3-16 ins. long.

While the heavy spring shown starts the braking edges into action, it is the descending weight which forces them into the wood until they are horizontal and bear against the stops as shown. The spring is no longer necessary, as an operating agent, after the noses of the blades have reached the point where they catch the wood of the guides.

A small upward movement of the drawbar of the cage (such as might be caused if a length of rope were following the falling cage and became momentarily caught) will not cause the withdrawal of the blades. Only a fresh connection of the rope to the cage, and the raising of the latter, will do this—a point in which Prof. Undeutsch's catch differs from all others. This device weighs 895 lbs.

Prof. Undeutsch has devoted much study to the subject of mine hoisting and its attendant dangers.* A further quotation from his letter, previously mentioned, may be of interest.

The writer was one of the first, at the time of the German Exhibition at Berlin in 1889 for the prevention of accidents, to point out that the dangerous portion of the hoisting rope was not near the sheave, as was then generally accepted, but was in the immediate neighborhood of the cage itself, both due to shock and to rusting and corrosion produced by acid mine water.

The results of a number of experiments on the latter subject were published by the author in the "Oesterreichischen Zeitschrift fur Berg—und Huttenwesen," 1892, and in a pamphlet entitled "Strains of Suspended Prismatic Bodies Due to Static and Dynamic Stresses."

*The results of Prof. Undeutsch's experiments were published in pamphlet form in 1889, under the title "Experimental Proofs of the Dangerous Action to which Persons and Cages are Exposed on the Breaking of Hoisting Ropes" (Craz & Gerlach, Freiberg).

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The indicator used by the writer not only registered the shock to which the rope was exposed, but also the actual length of the portion exposed to the shock.

The conclusion arrived at from the foregoing is that taper ropes are undesirable, although, considered statically, they present some advantages. Prismatic (cylindrical) ropes are distinctly safer and stronger at their lower ends. As there are thus some objections to the use of taper ropes for great depths and heavy loads, the writer would suggest the use of electric hoists and stage winding.

The data on which the writer has based the majority of his experiments and deductions were derived from the rope statistics gathered by the Mines Department at Dortmund and Breslau, on the initiative of Bergrat Hiltrop and by the Freiberg Mines Department, at the writer's own suggestion.

The introduction of speed safeties to prevent overwinding may be looked upon as a direct result of the Freiberg statistics, for Prof. Menzel of Freiberg proved that in the period from 1884 to 1891, among 101 cases of breakage of ropes and chains, 20 accidents were directly due to overwinding of the cage against the sheave. A special inducement for the perfection of speed safeties was the offer of a prize by the Freiberg Mines Department.

The information concerning ropes, gathered by the Dortmund Mines Department, has been shown graphically by the writer on page 225 of his book. At the time, in 1871, when Hiltrop and the Dortmund Mines Department started, the keeping of rope records and the development of safety catches was in its infancy. At that time, and with the introduction of the older form of safety catch, it was generally accepted that the rope attached to the ascending heavy cage was the one most liable to break. The problem at that time, therefore, was merely catching the ascending cage from rest, so to speak.

The original views have long ago been proved to be fallacious in that, as often as not, it is the rapidly moving descending rope which breaks. The older safety catches in the latter case gave rise to tremendous shock

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to descending persons, and enormous damage to the cage and to the shaft timbering. These consequences gave rise to the deep distrust in safety catches evinced for some time by the Dortmund Mines Department and by experts. This led to the saying that "a good rope is the best safety catch."

Mr. von Sparre, of Dortmund, drew the writer's attention to the rope statistics gathered, and suggested that, in addition to the safety of good ropes, there would be additional security if the safety catches could be improved, particularly in the direction of their not only catching the ascending but also the descending cage with a minimum amount of shock.

With this object in view, the writer, 30 years ago, began his investigations and experiments with slender knife- and chisel-edge catches the reduction to a minimum of the shock on catching and braking; and later, also, his free-fall catch and indicator experiments, the invention of the shock measurer (energy indicator) and the regulation of the size and shape of the arms and catches to meet different conditions. The result of his labors is shown in the latest design as shown in the accompanying drawing.

The Commission tested the Undeutsch catch in June, 1906, and March, 1907. In the first trials the blades were adjusted for a maximum penetration of 1 in., the guides being 4½ ins. in width and of pitch pine. With the empty cage slipped from rest in the head frame, the cage and safety catch together weighing 2,400 lbs., the cage was stopped after a drop of only ⅞-in., the average penetration of the 12 blades being but 9/32 in. With a load of 1,600 lbs. added, and a permitted initial drop of 3 ft., the cage dropped less than a foot farther; not all of the blades penetrated, owing to the canting of the cage; but they held, and with small shock.

Altering the adjustment to give the blades but ½-in. penetration, the cage was given a sharp run down of 30 ft. with the same load as in the

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preceding, and then disconnected. It dropped 48 ft. 6 ins., including the 30-ft. start, and came to rest, the blades all having come into action at once after a total drop of 36 ft., and having required about 13 ft. in which to stop the fall. (This should be noted in particular, in that—given positiveness of operation, which the Undeutsch catch undoubtedly displayed—an extension of the stopping action of a safety catch minimizes shock to persons on the cage.)

In the tests nearly a year later, on pitch-pine guides worn down to about 3¾ × 3¾ ins., the blades were set so as to penetrate until the points were 2 ins. apart. The cage was run down rapidly from the surface to a depth of 400 ft., and the rope was disconnected automatically from the drum. The cage, with 480 ft. of rope, was brought to rest after a fall of only 30 ft.; the velocity at the instant of disconnection being about 2,500 ft. per min. No damage was done, save that the knife edges entered the guides about ½-in. on each side, scoring out that amount of timber.

The results of these trials proved the Undeutsch device to be thoroughly reliable, simple and positive in its operation, and free from the objections of shock and damage to guides.

TESTS OF THE SCHWEDER* SAFETY CATCH.—The unique feature of this catch, shown in Fig. 5 without any attached cage, is that it is operated by carbonic acid gas at a pressure of 800 lbs. per sq. in., carried in a cylinder on the top of the gear. Upon the breakage of the rope, a spring actuates a lever which opens a valve and admits the gas to two 4-in. cylinders, placed close to the shaft guides. The inner cylin-

*K. Schweder, Acting Consulting Mechanical Engineer, A. Goerz & Co., Ltd., Johannesburg

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ders, within these, are forced out by the pressure and drive brake shoes directly against the guides.

The arrangement of the gas cylinder, operating cylinders and brake shoes, with relation to the guides, is shown best in the plan view in Fig. 5. The high pressure of the stored gas, multiplied by the cylinder area, gives tremendous pressure on the brake shoes—over 10,000 lbs. The weight of the entire device is 369 lbs.

That this catch strongly appealed to the Commission is shown by the fact that, during nine months, tests were conducted on seven different occasions. Its adaptability to use with steel guides (which none of the other devices possess, excepting the Wilkinson) also strongly recommended it.

At the first trials the brake shoes were found to have insufficient area to hold, and they were accordingly enlarged. Ultimately, after trials and suitable adjustments of load and of cylinder size, the Schweder catch operated satisfactorily under all imposed conditions, on wooden guides (4 × 4-in. pitch pine). The brakes brought the cage to rest with varying lengths of slide—25 to 30 ft.—with a running downward start before release. Gas pressures of from 800 to 900 lbs. per sq. in. were used. The total weight of the moving system in these trials on wood guides was about 3,100 lbs. With long running starts of several hundred feet, load about 2,500 lbs. total (including weight of cage and mechanism), and 4 × 4-in. pitch-pine guides worn to 3¾ × 3¾ ins., the device worked satisfactorily when the cage was released at a downward speed of 2,200 ft. per min. A previous and similar test, on similarly worn guides, had resulted in failure; whereupon means were added to allow for wear in the guides.

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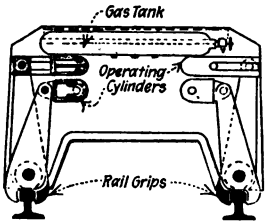

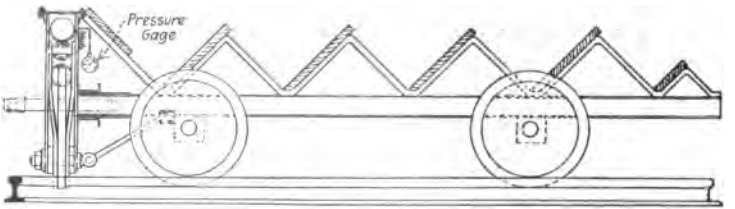

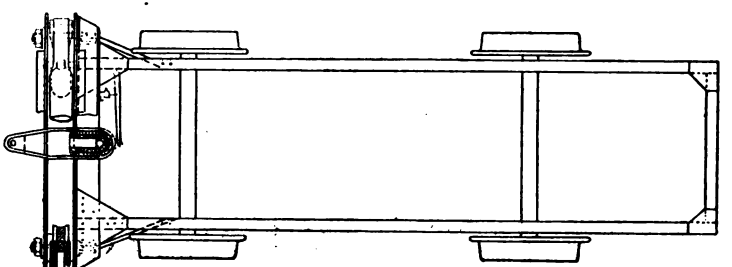

FIG. 6. THE SCHWEDER SAFETY-CATCH MECHANISM AS APPLIED TO PASSENGER SKIPS IN INCLINED SHAFTS.

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With steel guides the Schweder catch proved eminently successful. The guides were 60-lb. steel rails. With a total suspended weight of 2,880 lbs., a 30-ft. running downward start, and release at a speed of 1,020 ft. per min., with 92 ft. of rope attached to the cage, the latter was stopped after a further drop of about 21 ft. And *with the rails well greased*, under the same conditions, save that the downward speed of the cage was 30 *ft. per min. greater*, the cage was stopped in less than 15 ft. The gas pressure used was 900 lbs. per sq. in.; in the second trial, 15 minutes after the cage had been stopped, it was 780 lbs. per sq. in.

A modification of the Schweder device, suitable for use on passenger skips in inclined shafts, is shown in Fig. 6. From an examination of the end elevation it will be seen that the operating cylinders actuate, for each rail, two levers; these levers grip the rails as would a pair of pliers, holding the car. The Commission made no recommendation of this modification of the Schweder catch (see paragraph 168 of the report).

THE WILKINSON SAFETY CATCH.—Although, as stated in paragraph 165 of the report, this catch proved unsuccessful and was finally abandoned in favor of the Schweder catch—though the Wilkinson catch was designed for use with steel as well as wooden guides—it may be of interest to note that it consists of scissors-like levers mounted beneath the cage, operated both by springs and by the weight of the cage. Steel grips are brought into action, which clutch the sides of the guides.

THE BERRY CROSSHEAD FOR BUCKET SINKING.—As stated in paragraph 178 of the report, this device bears the endorsement of the Commission for use in bucket sinking. No tests

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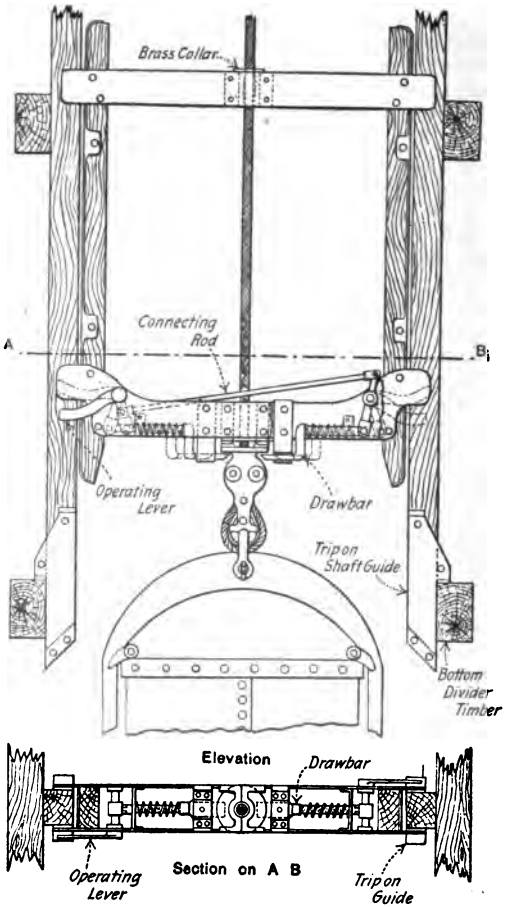

Fig. 7. The Berry Crosshead Guide, for Use in Shaft Sinking with Buckets.

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were made of this crosshead at the time of the other tests covered in the foregoing abstract.

Referring to Fig. 7, the steel "trips" on the shaft guides are at the bottom set of the shaft. When the bucket is lowered to this point, the levers at each side of the crosshead at the bottom are raised by the trips, and the drawbars locking the bucket and crosshead together are pulled back. (The rope passes through brass collars in the horizontal members of the crosshead, and runs freely therein).

When the crosshead is released from the bucket, it remains on the guides at the bottom set and the bucket runs on down to the sump, swinging free below the crosshead. On the up trip, the rope runs freely in the brass collars until the bucket reaches the crosshead, when the removal of the weight of the crosshead from the levers releases them and locks bucket and crosshead together.

A Combined Electric Lighting and Signaling Device for Vertical Sinking.

In "Annexure No. 4" to the report there is an illustrated description of an improvement in electric lighting and signaling apparatus for vertical shafts during the sinking period.

In past applications of electric lighting to shaft sinking, usually by winding the conducting cable on a drum, in some cases the drum has been operated on the surface; but at depths greater than 500 ft. the more common method has been to have about 300 ft. of cable on the drum, making it necessary to lower the hoisting winch bodily with every 200-ft. increase in depth. Both these arrangements require the breaking of the circuit every time the lamp is raised or lowered.

The equipment illustrated in the report is the invention of Mr. R. H. Gould, and combines both

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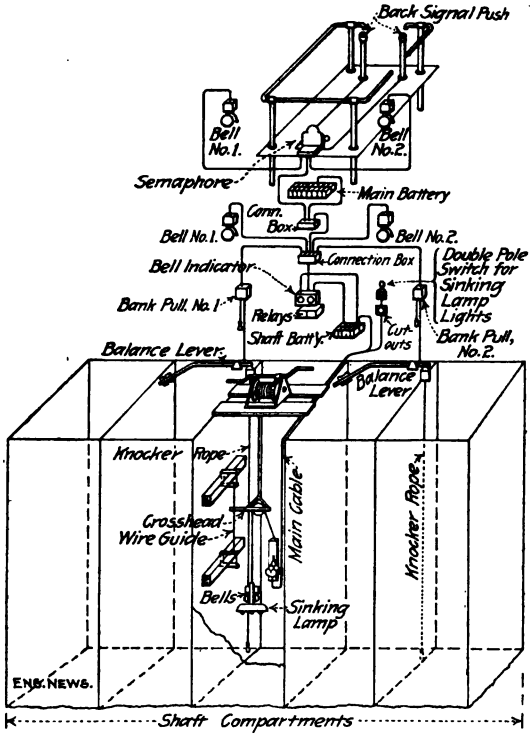

Fig. 8. Diagram of Circuits in the Gould Electric Lighting and Signaling Apparatus for Vertical Shaft Sinking.

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electric lighting and signaling facilities. In Mr. Gould's description of the apparatus, he says:

The winch remains on the surface, and on it is wound a comparatively thin steel rope of $^{3}/_{16}$-in. diameter, by which the crosshead (see Fig. 8) is suspended. The sinking lamp, to which are also fixed the bells, is suspended by a 4-core cable protected with a braiding of phosphor-bronze wire; the cable is led over the sheave of the crosshead, and is fastened at its other end by a clamp, suitably fixed to two dividers. The necessary connections are made here for the lights, as well as for the bells; these connections are permanent as long as the clamp remains in this position. When the lamp is to be raised, the crosshead is pulled up by the winch. To prevent the crosshead turning, a guide-wire about 180 ft. in length is provided.

The cable is about 330 ft. long, and as the clamp is fixed at first about 80 ft. above the bottom of the shaft, it follows that the clamp and guide-wire must be shifted down for about every 250 ft. of shaft sunk. The lowering of the whole arrangement can be done in a few hours. The clamp is fixed with two U-shaped bolts to two of the dividers. After shifting the clamp and guide down, the permanent wire connecting the clamp need only be lengthened.

Since the winch remains on the surface, the lamps remain at the bottom of the shaft until after the men have ascended from lighting the blasting fuse, and can be lowered again in advance of the men descending. The lamp is, therefore, always at the bottom when men are below, and it is for this reason, and because no disconnections are made, that it is admirably adapted to carry bells, which not only permits of all signals given in the shaft being heard at the bottom, but provides return signals at the bottom of the shaft.

All signals in the shaft are given with the ordinary knocker line. At the top of each working compartment a balance lever is provided, the knocker line being attached to this lever by a clamp, which permits of the line being lowered conveniently as the shaft is deepened.

The movement of the balance lever is transmitted to an ordinary electric bell-pull which causes a bell to ring at

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the bank and in the engine-room, at the same time opening a relay and the semaphore, and the relay rings the corresponding bell on the sinking lamp through an independent battery. The importance of this relay will be understood when it is mentioned that whatever may happen to the sinking lamp or bells thereon—the bell wires may be severed, or they may be short circuited—nothing will interfere with the correct delivery of the signals to the surface.

The arrangement is really only a new combination of existing apparatus, with the exception of the semaphore; the latter is fitted with one white and one red disk, and is placed in front of the engine driver, and shows him from which compartment the last signal was given.

The Gould apparatus has been in satisfactory operation for over three years at the Geduld shaft, in the Transvaal. Fig 9 is a photograph of the sinking lamp in use there, showing the bells beneath the bonnet.

Extract from the Mining Regulations of the Transvaal.*

SECTION IV.

Articles 19-31....Winding.—General.
Articles 32-39....Winding.—Signals.
Articles 40-42....Winding.—Raising or lowering persons.

GENERAL.

18. Windlasses, whims, whips, and the like in use at or in workings shall be provided with a stopper, pawl, or some other reliable holder, and care must be taken that the hooking on and off of buckets, kibbles, or other receptacles is done without danger to the workmen.

19. Where winding is effected by means of an engine, an adequate brake shall be attached to every drum and kept in proper working order. Such brake must be so arranged that, be the engine at work or at rest, it can be easily and safely manipulated by the engine-driver

*We have, with the exception of Americanizing the spelling, printed these regulations verbatim. A number of terms not in common use in this country we have allowed to stand unchanged. Throughout the entire publication of the report we have retained the word "winding" instead of substituting the word "hoisting," more common among American mining men.

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when standing at the levers controlling the engine. Spare parts—brake-blocks, etc.—shall always be kept in stock at the mine. The Inspector of Mines shall at all times have the power to order or conduct a test of the efficiency of all brakes.

20. The connection between rope and bucket, kibble, or other means of conveyance must be of such a nature that no accidental disconnection can take place.

21. All ropes used for winding purposes shall be of approved quality and manufacture, free from any defect. Wire ropes only shall be used for winding persons, except in prospecting shafts and winzes of a maximum depth of 100 ft. Wire ropes whether used for winding material or persons, shall be made of steel, and the wires used in the construction of the ropes shall be of sizes suitable for use with the sheaves and drums fitted. At the request of the Inspector of Mines, an adequate sample from the end of any winding rope shall be supplied to him.

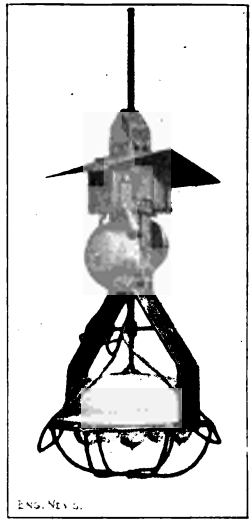

Fig. 9. Sinking Lamp Used with Gould Apparatus, Showing Bells.

22. When tools, wood, or other materials are to be let down or hoisted up in a shaft, their ends, if projecting above the top of the bucket, kibble, or other vehicle, shall be securely fastened to the winding rope or to the bow of the receptacle.

23. In sinking shafts, the bucket or other means of conveyance shall only be filled up to the level of the brim. Before the bucket or other means of conveyance leaves the top or bottom of

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the shaft, it shall be steadied under the supervision of the workman in charge.

24. In no case shall any cage, skip, kibble, or other receptacle be directly lowered to the bottom of a shaft when men are working there, but must be stopped at least 15 ft. above the bottom until the signal to lower it further has been given by one of the sinkers thereat. This rule shall not apply to shafts in which the sinkers are not more than 50 ft. from the banksman.

25. Ladder-ways shall be provided in all shafts in the course of sinking to within such a distance of the bottom as will secure them from damage in blasting, and from the end of such ladder-ways chains or chain-ladders shall be extended to the bottom of the shaft.

26. Vertical shafts exceeding 100 ft. in depth shall be provided with guides for kibbles, unless exempted in writing by the Inspector of Mines. Such guides shall always be kept extended down to the lowest set of timbers; also the crosshead shall be allowed to travel to the lowest set but one, and in no case shall the lowest set of timbers be more than 50 ft. from the shaft bottom.

27. Persons engaged in sinking operations in a shaft bottom during the winding of rock, material, or water, or while timbering or other repairs are taking place, shall be protected from the danger of falling material, tools, etc., by a covering extending over the whole area of the shaft, such covering in the case of vertical and steeply inclined shafts to be not more than 50 ft. from the shaft bottom, sufficient space only being left for the passage of the sinking conveyance or conveyances (skip, bucket, or kibble).

No person engaged in sinking operations in a vertical shaft, or a shaft dipping at 60° or over, shall be permitted to work therein, unless he wears a hard hat of a type approved by the Government Mining Engineer. In the case of a colored employee, such hat shall be provided by the manager. Should a working shaft be sunk deeper while ordinary winding is going on, the men employed at the bottom of such shaft shall be securely protected by a cover overhead.

28. In vertical shafts where cages are used, the land-

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ing place of each winding compartment shall be provided with a self-closing cover, gate, or gates.

29. At every shaft station where it is necessary for workmen to pass from one side of the shaft to the other, provision shall be made for them to do so without entering or crossing a winding compartment; such passage shall be securely fenced off from moving parts of machinery.

30. Entering or crossing a winding compartment of a shaft is prohibited, except to ascend or descend, and for purposes of repairs. This regulation shall not apply to persons employed in timbering vertical shafts while sinking operations are being carried on.

31. No winding shall be permitted while repairs in the winding compartment are being made, beyond what is necessary for such repairs. This shall not prohibit persons from working below the lowest point from which winding is taking place, provided that such persons are securely protected by a suitable covering. The word "repairs" mentioned in this regulation and in regulation 30 shall be taken to include the oiling of rollers and pulleys.

SIGNALS.

32. Every winding shaft, if exceeding 50 ft. in depth and not exempted in writing by the Inspector of Mines, shall be provided with some efficient means of interchanging distinct and definite signals between the top of the shaft and the lowest level from which winding is carried on, and the various intermediate stations for the time being in use. The workmen at the bottom of a shaft where work is carried on shall be provided with efficient means of interchanging distinct signals with the surface.

33. Where one or more compartments in a shaft are set apart for the hauling of persons, in addition to the system of signals between the top and bottom of the shaft provided for in regulation 32, a separate set of signals must be provided, so that signals may be exchanged between the shaft-top and the engine-driver.

34. The engine-driver is prohibited from starting his engine before he has received a distinct signal.

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35. Only persons duly authorized by the manager, mine overseer, or shift bosses are allowed to give a signal for the winding of material. Special instructions shall be issued by the manager forbidding access to the signal wires to any person other than those in charge of them, and special care shall be taken to guard against the signal wires being accidentally put in operation.

36. At every shaft or shaft station where persons are regularly allowed to ride, signals for raising or lowering a person or persons shall be given only by qualified European banksmen and onsetters, who shall be responsible for the observaince of the rules referred to in regulation 42 (e), (f), (g), and (i), and that the correct signals are given and the doors and covers of the cages properly fixed. The manager may give permission to responsible persons to use the mine signals for their own conveyance.

In signaling, the following shaft signals shall be used—knocks or rings:

1—RAISE when engine at rest.
1—STOP when engine in motion.
2—LOWER.
3—MEN about to ascend or descend.
3—IN REPLY. MEN may enter the cage or other conveyance.

In no case shall any person enter a cage or other conveyance until the back signal "3" has been received.

The engine-driver when receiving the signal "1" or "2," signifying to raise or lower any person, must wait at least ten seconds before starting to wind, except under the circumstances set forth under regulation 39.

37. Special signals, in addition to the above, may be used at any mine, provided they are easily distinguishable by their sound or otherwise from the foregoing code, and do not interfere with it in any way.

38. The before-mentioned code of signals, as well as any special signals that may be in use on a mine, shall be painted on a board or enamelled plate, not less than 20 ins. × 20 ins., in the form of a distinctly legible notice, and shall be posted up in the engine-room, and at the top of the shaft, and at all shaft stations for the time being in use.

39. In shaft sinking, special care must be taken that

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the engine-driver is notified by a prearranged signal when blasting is about to take place, so that he may be ready instantly to raise persons employed in blasting on receipt of the final signal.

RAISING OR LOWERING PERSONS.

40. No winding plant shall be used for the raising or lowering of persons, unless the special written permission of the Inspector of Mines has been granted. Permission shall not be granted unless the foregoing regulations and the following subsections, namely, (a), (b), (c), (d), (e), (f), (g), (h), (i), (j), and (k) of this regulation (40) have been proved to the satisfaction of the Inspector of Machinery by actual test to have been complied with so far as they are applicable to each individual case.

(a) The winding engine shall be such that:

(1) Running at various speeds with light and heavy loads, it can be readily slowed and stopped, and after stopping can be immediately started again in either direction by the engine-driver.

(2) It can lift from bottom to top of shaft the maximum unbalanced load on one drum. This provision shall not apply in cases where other means exist enabling persons employed below to reach the surface.

(3) Each winding drum unclutched from the engine can be maintained in a position of rest with no more slipping than 1 ft. by means of its own brake or brakes, (a) while bearing its maximum working load when winding persons, and (b) when this load is increased to the extent of doubling the authorized load of the cage or skip. In estimating this authorized load, 150 lbs. weight shall be allotted for each person.

(4) In the case of a hoist where no part of the rope is rigidly fixed to the drum, there shall be no dangerous slipping of the rope on the drum under any possible working conditions.

(b) There shall be on the drum of the winding engine such flanges or horns, and also, if the drum is conical or spiral, such other appliances as may be sufficient to prevent the rope from slipping.

(c) There shall be not less than 3 rounds of rope upon the drum when the cage or other conveyance is at the lowest point of the shaft from which hoisting is effected.

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The end of the rope shall, where applicable, be properly fastened round an arm or the shaft of the drum.

(d) Every engine used in raising or lowering persons shall be provided with a reliable depth indicator, in addition to any marks on the rope, which will clearly and accurately show to the engine-driver at his driving seat at all times the position of the cage or other conveyance in the shaft, and which will, moreover, in shafts exceeding 300 ft. in depth, ring a bell in the engine room when the conveyance is 60 ft. from the top landing place.

(e) Where difference of gradient in a shaft necessitates reduction of winding speed, such positions shall be plainly marked on the depth indicator.

(f) A reliable speed indicator or governor must be attached to the winding engine, if considered necessary by the Inspector of Mines.

(g) Some suitable automatic device to prevent over-winding of cages or other conveyances shall, where possible, be provided at every winding shaft or winding engine. If the winding apparatus cannot be provided with some automatic contrivance to prevent over-winding, then the cage or other conveyance, when men are being raised, shall not be wound up at a speed exceeding 250 ft. per min, after the cage or other conveyance has reached a point in the shaft to be fixed by the Inspector of Mines.

(h) The headgear shall be carried without obstruction to the skip-way to such a height as to allow a clearance of at least 25 ft., in which the cage or similar contrivance can travel freely in case of an over-wind. The Government Mining Engineer may grant permission for headgears which were erected previous to these regulations coming into force, and which do not comply with the above conditions, to be used.

(i) Winding ropes shall not be used for raising or lowering persons when, owing to deterioration, the breaking strain has become reduced to below six times the maximum working load. In case a winding rope is used for other purposes besides the transport of persons, the maximum working load permitted, when raising or lowering persons, shall not exceed 0.85 of the maximum load when the rope is in use for other purposes. The maximum working load shall include the weight of rope

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in the shaft when the conveyance is at the lowest working point, as well as the weight of the skip, cage, or other conveyance and its contained load.

(j) Winding ropes newly put on, as also the connecting attachments between the rope and the cage, skip, or other conveyance, shall be carefully examined and properly tested as to their working strength by some competent and reliable person authorized thereto by the manager, and shall be used for the ordinary transport of persons in shafts only after having been run two complete trips up and down the working portion of the shaft, the cage or skip being loaded to the full authorized extent. The result of the above examination shall be immediately recorded in a book which shall always be accessible to the Inspector. This book, to be termed the rope record book, shall contain the following particulars of winding ropes:

(A) Maker's data of rope when new or a copy thereof certified to by the manager:
Name and address of manufacturer.
Date of manufacture.
Date of purchase.
Length of rope in feet.
Diameter and circumference of rope in inches or (in the case of flat ropes) width and thickness of rope.
Weight per foot in pounds.
Construction of rope:
Number of strands.
Class of core.
Construction of strands:
Number of wires.
Diameter of wires (decimals of an inch.)
Class of core.
Class of steel of which wire is made.
Breaking stress of steel of which wire is made (tons of 2,000 lbs. per sq. in.).
Breaking load of rope (tons of 2,000 lbs.)
(B) History of rope in use:
Name of shaft in which rope is used.
Compartments in which rope is used.
Date on which rope was put on.
Dates of shortening.

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Dates of re-capping.
Dates of turning end for end.
Dates of tests after shortening.
Breaking stress of wires at these tests.
Date when rope was taken off.

Each record shall be signed by the person responsible for the required examination.

(k) Cages, skips, or other conveyances used in vertical or steeply inclined shafts, except during sinking operations, shall have a proper roof or cover; and shall have proper safety catches where applicable. Cage entrances shall be fitted with doors so as to prevent any portion of the body of any person riding therein from accidentally coming into contact with the timbering or sides of the shaft, and the doors must be constructed in such manner that they cannot open of themselves.

41. Prospecing shafts not exceeding 100 ft. in depth, where winding is done by manual or animal power, shall be exempted from the provisions of the preceding regulation.

42. Where winding in shafts in accordance with regulation 40 is permitted, the following regulations shall be strictly observed:

(a) One, or more than one, competent person, specially deputed by the manager for the purpose, and whose name or names must be registered by him in a record book—such book to be termed the machinery record book—shall carefully examine:

(1) At least once each day, the winding ropes and their attachments to the cages and drums, the brakes, depth indicators, the cages and their safety catches, the pulley wheels, and all and every external part of the winding arrangements upon the proper working of which life depends.

(2) At least once a week the guides and the winding compartments generally, the signalling arrangements, and the external parts of the winding engine.

(3) At least once a year the winding engine as to the working condition of the internal parts.

(4) At least once a month the structure of the rope, for the purpose of discovering the amount of deterioration of same. For the purpose of this examination,

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which shall be made by the Resident Mechanical Engineer in charge of the machinery at the mine, the rope must be thoroughly cleaned at selected places, and the Resident Mechanical Engineer shall note any reduction in diameter and proportion of wear in the rope, and shall record same in the machinery record book.

(5) At least once in six months in the case of a round rope, and once in three months in the case of a flat rope, the rope shall be re-capped and a portion of length not less than half the circumference of the pit-head sheave cut off the lower end. The portion of the rope removed shall be tested in the mechanical laboratory of the Mines Department at the expense of the owner (at a cost not to exceed £4) to whom a certificate shall be furnished. At each occasion of re-capping, the connection between the rope and the skip, cage, or other conveyance shall be annealed. A true report of the result of every examination above mentioned, shall be recorded without delay in the machinery record book, which must be kept at the mine especially for the purpose, and shall be signed by the person who made the inspection. This record book shall at all times be open for the inspection of the Inspector of Mines and the Inspectors of Machinery. Should, as the result of such examination, any weakness or defect be discovered by which life or limb may be endangered, the defect shall immediately be reported to the manager and remedied, and no person shall be lowered or raised until the defect is made good.

(b) So soon as the rope becomes defective it shall no longer be used for the transport of persons, unless the damaged part be at the end and be cut off.

(c) Ropes out of which any defective portion has been cut and the ends again spliced, and ropes which have been previously in use in places beyond the manager's control, shall not be used to raise or lower persons.

(d) At every mine where persons are raised or lowered, at least one spare rope of the description as provided for in regulation 40 (j) shall always be kept in reserve ready for use.

(e) While persons are riding in a shaft, the winding of mineral or material must be discontinued, except

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where a separate engine is used for raising or lowering persons. No workman shall take with him in the cage or bucket any heavy articles, especially drills or other tools, except for the purpose of shaft repairs. This rule shall not apply to any onsetter or banksman, who shall be especially authorized in writing by the manager to travel with and distribute such articles.

(f) No one is allowed to ascend or descend a shaft on the side or bow of a skip, or on the top of a loaded truck, skip, or bucket. Riding in partially loaded cages, skips or buckets is only permitted to persons in charge of underground works, sinkers, and to workmen employed to do repairs in the shaft. The same applies to unprotected cages, skips or buckets in vertical or steeply inclined shafts.

(g) In no case shall a greater number of persons ride in any cage or other conveyance at any one time than can be conveniently accommodated therein with safety. The number of persons allowed to ride at one time in a cage or other conveyance shall be fixed by the Inspector of Mines, and shall be kept posted up at each landing place.

(h) No person travelling in a cage or other conveyance shall change his place therein while the conveyance is in motion.

(i) After any stoppage of winding for repairs, or for any other purpose exceeding an hour's duration, each cage or other conveyance, before any person is allowed to ride therein, must be run a complete trip up and down the working portion of the shaft at least once, with a view of ensuring that everything is in good working order.

(k) When winding persons, the engine-driver shall in no case be allowed to run the engine at a greater speed than that fixed upon when the permission to use the engine for the purpose was granted, and he shall take care that shocks in starting and bringing the engine to rest are avoided, and that cages or other conveyances are set down gently at stopping places.

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